CHEMICAL BONDING AND MOLECULAR STRUCTURE

FACT/DEFINITION TYPE QUESTIONS

1. The attractive force which holds various constituents (atoms, ions etc.) together in different chemical species is called a
(a) chemical bond (b) chemical compound
(c) ionic bond (d) covalent bond

2. The evolution of various theories of valence and the interpretation of the nature of chemical bonds have closely been related to the developments in the understanding of
(a) structure of atom
(b) electronic configuration of elements
(c) periodic table
(d) All of the above

3. Who provide explanation of valence based on intertness of noble gases ?
(a) Lewis (b) Kössel-Lewis
(c) Langmuir (d) Sidgwick & Powell

4. In the formation of a molecule which of the following take part in chemical combination?
(a) cation (b) anion
(c) valence electron (d) inner shell electron

5. Which of the following do(es) not represent correct Lewis symbols?

(a) I, IV & V (b) II, III & IV
(c) II only (d) II & III

6. The bond formed as a result of the electrostatic attraction between the positive and negative ions is termed as ...
(a) Chemical bond (b) Electrovalent bond
(c) Co-ordinate bond (d) Covalent bond

7. Cation and anion combines in a crystal to form following type of compound
(a) ionic (b) metallic
(c) covalent (d) dipole-dipole

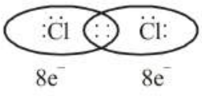
8. Electrovalence of calcium and chlorine respectively is
(a) + 2, – 1 (b) + 1, – 1
(c) + 1, – 2 (d) + 2, – 2

9. When a metal atom combines with non-metal atom, the non-metal atom will
(a) lose electrons and decrease in size
(b) lose electrons and increase in size
(c) gain electrons and decrease in size
(d) gain electrons and increase in size

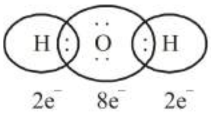
10. Who introduced the term covalent bond ?
(a) Lewis (b) Langmuir
(c) Nyholm and Gillespie (d) Heitler and London

11. Which of the following is/are not the condition(s) for Lewis dot structure?
(i) Each bond is formed as a result of sharing of an electron pair between the atoms.
(ii) From the two combining atoms only one atom contribute electron(s) to the shared pair.
(iii) The combining atoms attain the outer shell noble gas configurations as a result of the sharing of electrons.
(a) (i) and (iii) (b) (ii) and (iii)
(c) (ii) only (d) (iii) only

12. Which of the following does not represent the correct Lewis dot structure?



(A)



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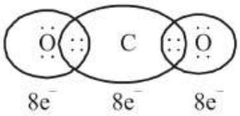
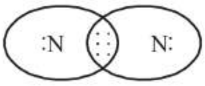


(C)

(a) A (b) B
(c) C (d) A and C

13. Which of the following statements are correct based on given Lewis dot structure ?

(i)



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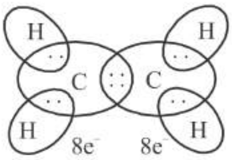
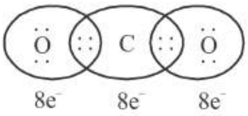
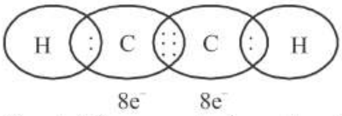


(iii)

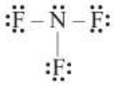


(iv)

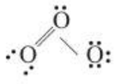


(a) (i) and (iv) represents formation of triple bond
(b) Only (iii) represents formation of double bond
(c) Only (ii) represents formation of single bond
(d) (ii) and (iii) both represents formation of single bond.

14. Which of the following Lewis representation of the molecules NF_3, O_3 and HNO_3 is correct ?



I



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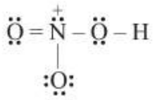


III

Choose the correct option(s).

(a) Only I (b) Only II
(c) Only III (d) I, II and III

15. In N_2 molecule, the number of electrons shared by each nitrogen atom is

(a) 1 (b) 2
(c) 3 (d) 5

16. Which of the following represents the Lewis structure of N_2 molecule?

(a) ${}_{\times}^{\times}N \equiv N_{\times}^{\times}$ (b) ${}_{\times}^{\times}\overset{\times\times}{N} \equiv \overset{\times\times}{N}{}_{\times}^{\times}$

(c) ${}_{\times}^{\times}\overset{\times\times}{N}{}_{\times}^{\times} - \underset{\times\times}{\overset{\times\times}{N}}{}_{\times}^{\times}$ (d) ${}_{\times}^{\times}\underset{\times\times}{\overset{\times\times}{N}} = \underset{\times\times}{\overset{\times\times}{N}}{}_{\times}^{\times}$

17. Which of the following shows the Lewis dot formula for CO_2 ?

(a) $:\ddot{O}::C::\ddot{O}:$ (b) $:\underset{..}{\ddot{O}}:\ddot{C}::\ddot{O}:$

(c) $:\ddot{O}::C:\underset{..}{\ddot{O}}:$ (d) $:\underset{..}{\ddot{O}}:C:\underset{..}{\ddot{O}}:$

18. Which of the following is the correct electron dot structure of N_2O molecule?

(a) $:N = N = \overset{..}{O}:$ (b) $:N = \overset{+}{N} = \underset{..}{\overset{..}{O}}:^{-}$

(c) $\underset{..}{\overset{..}{N}} = \overset{..}{N} = \overset{..}{O}:$ (d) $:N = N = \underset{..}{\overset{..}{O}}:$

19. What is X, Y and Z in the following expression of formal charge.

Formal charge (F.C) on an atom in a Lewis structure

$$= X - Y - \frac{1}{2}(Z)$$

(a) X = Total number of non bonding electrons
Y = Total number of bonding electrons
Z = Total number of valence electrons in the free atom

(b) X = Total number of valence electrons in the free atom
Y = Total number of bonding electrons
Z = Total number of non bonding electrons

(c) X = Total number of valence electrons in the free atom
Y = Total number of non bonding electrons
Z = Total number of bonding electrons

(d) X = Total number of electrons in the free atom
Y = Total number of non bonding electrons
Z = Total number of valence electrons

20. The lowest energy structure is the one with the .... formal charges on the atoms.

(a) smallest (b) highest
(c) zero (d) negative

21. In PO_4^{3-} ion, the formal charge on each oxygen atom and P—O bond order respectively are

(a) –0.75, 0.6 (b) –0.75, 1.0
(c) –0.75, 1.25 (d) –3, 1.25

22. In the cyanide ion, the formal negative charge is on

(a) C
(b) N
(c) Both C and N
(d) Resonate between C and N

23. What are the exceptions of the octet rule ?

(a) The incomplete octet of central atom
(b) An odd number of electrons on central atom.
(c) Expanded octet of the central atom
(d) All of these

24. In which of the following molecules octet rule is not followed?

(a) NH_3 (b) CH_4
(c) CO_2 (d) NO

25. In which of the following compounds octet is complete and incomplete for all atoms :

	Al_2Cl_6	$Al_2(CH_3)_6$	AlF_3	Dimer of $BeCl_2$	Dimer of BeH_2
(a)	IC	IC	IC	C	C
(b)	C	IC	IC	C	IC
(c)	C	IC	C	IC	IC
(d)	IC	C	IC	IC	IC

(**Note :** C for complete octet and IC for incomplete octet.)

26. Which of the following molecule(s) obey the octet rule?

(i) $[BF_4]^-$, (ii) $[AlCl_4]^-$, (iii) SO_2, (iv) CCl_4

(a) (i), (ii), (iii), (iv) (b) (ii), (iii), (iv)
(c) (i), (iii), (iv) (d) (i), (ii), (iii)

27. Among the following the electron deficient compound is
(a) BCl_3 (b) CCl_4
(c) PCl_5 (d) $BeCl_2$

28. Which of the following is the electron deficient molecule?
(a) C_2H_6 (b) B_2H_6
(c) SiH_4 (d) PH_3

29. Which of the following compounds does not follow the octet rule for electron distribution?
(a) PCl_5 (b) PCl_3
(c) H_2O (d) PH_3

30. A pair of compound which have odd electrons in the group NO, CO, ClO_2, N_2O_5, SO_2 and O_3 are
(a) NO and ClO_2 (b) CO and SO_2
(c) ClO_2 and CO (d) SO_2 and O_3

31. Which of the following statements is incorrect ?
(a) The formation of ionic compounds depend upon the ease of formation of the positive and negative ions from the respective neutral atoms.
(b) Formation of ionic compounds depend upon arrangement of the positive and negative ions in the solid.
(c) Formation of positive ion involves addition of electron(s) while that of negative ion involves removal of electron(s).
(d) None of these

32. Complete the following statement by choosing the appropriate option.
Ionic bonds will be formed more easily between elements with comparatively ____**A**____ and elements with comparatively high negative value of ____**B**____.
(a) A = low electronegativity
B = ionization enthalpy
(b) A = low ionization enthalpy
B = electron gain enthalpy
(c) A = high ionization enthalpy
B = electron gain enthalpy
(d) A = high electronegativity
B = ionization enthalpy

33. In ionic solids how crystal structure get stabilized
(a) By the energy released in the formation of crystal lattice.
(b) By achieving octet of electrons around the ionic species in gaseous state.
(c) By electron gain enthalpy and the ionization enthalpy.
(d) None of these

34. Energy required to completely separate one mole of a solid ionic compound into gaseous constituent ions is called ....
(a) Ionisation enthalpy
(b) Electron gain enthalpy
(c) Bond dissociation enthalpy
(d) Lattice enthalpy

35. The effect of more electronegative atom on the strength of ionic bond
(a) increases (b) decreases
(c) remains the same (d) decreases slowly

36. Which of the following combination will form an electrovalent bond ?
(a) P and Cl (b) NH_3 and BF_3
(c) H and Ca (d) H and S

37. Among the following which compound will show the highest lattice energy ?
(a) KF (b) NaF
(c) CsF (d) RbF

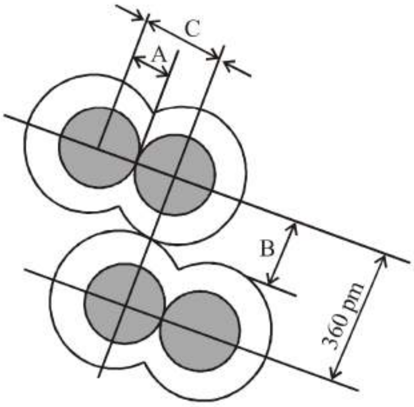
38. Which of the following bond will have highest ionic character?
(a) H–I (b) H–F
(c) H–Cl (d) H–Br

39. Which of the following pairs will form the most stable ionic bond ?
(a) Na and Cl (b) Mg and F
(c) Li and F (d) Na and F

40. Which of the following methods is used for measuring bond length ?
(a) X-ray diffraction
(b) Electron-diffraction
(c) Spectroscopic techniques
(d) All of these

41. .... is measured as the radius of an atom's core which is in contact with the core of an adjacent atom in a bonded situation.
(a) van der Waal's radius
(b) Bond length
(c) Covalent radius
(d) Ionic radius

42. Following figure represent a chlorine molecule. Identify A B and C in the given figure.



(a) A = Bond length, B = van der Waal's radius
C = Covalent radius
(b) A = Covalent radius, B = Bond length
C = Ionic radius
(c) A = Ionic radius, B = van der Waal's radius
C = Covalent radius
(d) A = Covalent radius, B = van der Waal's radius
C = Bond length

43. Which of the following statement is correct?
(a) Amount of energy required to break one mole of bonds of a particular type between two atoms in a gaseous state is called bond enthalpy.
(b) The unit of bond enthalpy is kJ mol^{-1}
(c) Larger the bond dissociation enthalpy, stronger will be the bond in the molecule
(d) All of these

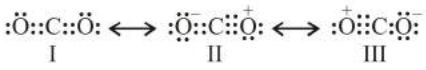
44. Complete the following statements.
With ____**A**____ in bond order, ____**B**____ increases and ____**C**____ decreases.
(a) A = increase, B = bond length, C = bond enthalpy
(b) A = decrease, B = bond enthalpy, C = bond length
(c) A = increase, B = bond enthalpy, C = bond length
(d) A = increase, B = bond angle, C = bond enthalpy

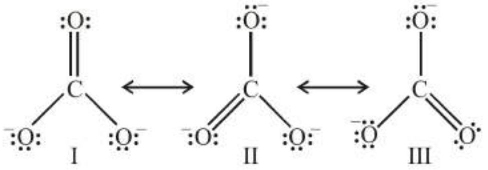
45. Which of the following molecules have same bond order ?

$$\underset{I}{H_2}, \underset{II}{Cl_2}, \underset{III}{CO}, \underset{IV}{Br_2}, \underset{V}{N_2}$$

Choose the correct option.
(a) I, II and IV have same bond order
(b) III and V have same bond order
(c) Both (a) and (b) are correct
(d) None of the above

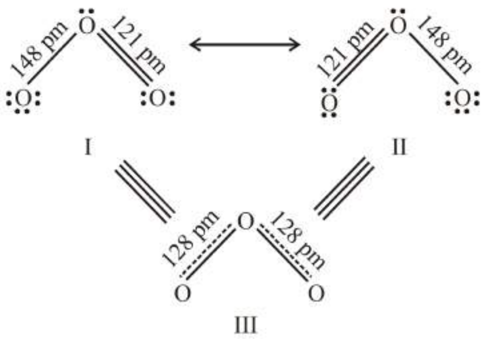
46. Which one of the following is not correct representation of resonance ?

A. 

B. 

Choose the correct option.
(a) Only A
(b) Only B
(c) Both A and B
(d) None of the above

47. Which of the following structure represents structure of O_3 more accurately?



(a) I
(b) II
(c) III
(d) I and II

48. Which of the following is/are misconception(s) associated with resonance ?
(i) The molecule exist for a certain fraction of time in one cannonical form and for other fractions of time in other cannonical forms.
(ii) The cannonical forms have no real existence.
(iii) There is no such equilibrium between the cannonical forms.
(a) (i) only
(b) (ii) and (iii)
(c) (i) and (iii)
(d) (iii) only.

49. The number of possible resonance structures for CO_3^{2-} is
(a) 2
(b) 3
(c) 6
(d) 9

50. Which one of the following is not the resonance structure of CO_2?
(a) $O=C=O$
(b) $^-O-C\equiv O^+$
(c) $^+O\equiv C-O^-$
(d) $O\equiv C=O$

51. All the bond lengths of sulphur – oxygen in sulphate ion, are equal because of:
(a) symmetry
(b) resonance
(c) high electronegativity of oxygen
(d) None of these

52. Resonance is due to
(a) delocalization of sigma electrons
(b) delocalization of pi electrons
(c) migration of protons
(d) Both (a) and (b)

53. Which one of the following pairs of molecules will have permanent dipole moments for both members ?
(a) NO_2 and CO_2
(b) NO_2 and O_3
(c) SiF_4 and CO_2
(d) SiF_4 and NO_2

54. The molecule which has zero dipole moment is
(a) CH_3Cl
(b) NF_3
(c) BF_3
(d) ClO_2

55. Which of the following has dipole moment?
(a) CO_2
(b) *p*-dichlorobenzene
(c) NH_3
(d) CH_4

56. Identify the non polar molecule in the following compounds
(a) H_2
(b) HCl
(c) HF and HBr
(d) HBr

57. A neutral molecule XF_3 has a zero dipole moment. The element X is most likely
(a) chlorine
(b) boron
(c) nitrogen
(d) carbon

58. Among the following, the molecule of high dipole moment is
(a) CCl_4
(b) NH_3
(c) H_2O
(d) $CHCl_3$

59. Which one of the following molecules is expected to have zero dipole moment?
(a) H_2O
(b) CO_2
(c) SO_2
(d) CaF_2

60. The correct order of dipole moments of HF, H_2S and H_2O is

(a) $HF < H_2S < H_2O$ (b) $HF < H_2S > H_2O$

(c) $HF > H_2S > H_2O$ (d) $HF > H_2O < H_2S$

61. The most polar bond is

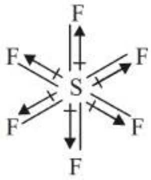
(a) C – F (b) C – O

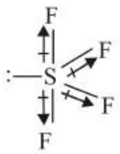
(c) C – Br (d) C – S

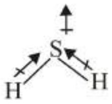
62. Which of the following possess dipole moment SF_6(a), SO_2(b), H_2S(c), SF_4(d) ?

(a) b and c (b) a and c

(c) b, c and d (d) a and b







63. According to Fajan's rule, covalent bond is favoured by

(a) Large cation and small anion

(b) Large cation and large anion

(c) Small cation and large anion

(d) Small cation and small anion

64. Arrange the following in increasing order of covalent character (i) NaCl, (ii) RbCl, (iii) $MgCl_2$, (iv) $AlCl_3$?

(a) (i), (ii), (iii), (iv) (b) (iv), (ii), (i), (iii)

(c) (ii), (i), (iii), (iv) (d) (iii), (i), (ii), (iv)

65. The correct sequence of increasing covalent character is represented by

(a) $LiCl < NaCl < BeCl_2$ (b) $BeCl_2 < LiCl < NaCl$

(c) $NaCl < LiCl < BeCl_2$ (d) $BeCl_2 < NaCl < LiCl$

66. Which of the following salt shows maximum covalent character?

(a) $AlCl_3$ (b) $MgCl_2$

(c) CsCl (d) $LaCl_3$

67. Polarisibility of halide ions increases in the order

(a) F^-, I^-, Br^-, Cl^- (b) Cl^-, Br^-, I^-, F^-

(c) I^-, Br^-, Cl^-, F^- (d) F^-, Cl^-, Br^-, I^-

68. The covalent bond length is the shortest in which one of the following bonds?

(a) C—O (b) C—C

(c) C≡N (d) O—H

69. Hydrogen chloride molecule contains

(a) polar covalent bond (b) double bond

(c) co-ordinate bond (d) electrovalent bond

70. Sodium chloride is an ionic compound whereas hydrogen chloride is mainly covalent because

(a) sodium is less reactive

(b) hydrogen is non-metal

(c) hydrogen chloride is a gas

(d) electronegativity difference in the case of hydrogen and chlorine is less than 2.1.

71. According to VSEPR theory the geometry of a covalent molecules depends upon

(a) the number of bond pairs of electrons

(b) the number of lone pairs of electrons

(c) the number of electron pairs present in the outer shell of the central atom

(d) All the above

72. The geometry of ClO_3^- ion according to Valence Shell Electron Pair Repulsion (VSEPR) theory will be

(a) planar triangular (b) pyramidal

(c) tetrahedral (d) square planar

73. In BrF_3 molecule, the lone pairs occupy equatorial positions to minimize

(a) lone pair - bond pair repulsion only

(b) bond pair - bond pair repulsion only

(c) lone pair - lone pair repulsion and lone pair - bond pair repulsion

(d) lone pair - lone pair repulsion only

74. Which of the correct increasing order of lone pair of electrons on the central atom?

(a) $IF_7 < IF_5 < ClF_3 < XeF_2$

(b) $IF_7 < XeF_2 < ClF_2 < IF_5$

(c) $IF_7 < ClF_3 < XeF_2 < IF_5$

(d) $IF_7 < XeF_2 < IF_5 < ClF_3$

75. The number of lone pair and bond pair of electrons on the sulphur atom in sulphur dioxide molecule are respectively

(a) 1 and 3 (b) 4 and 1

(c) 3 and 1 (d) 1 and 4

76. A molecule has two lone pairs and two bond pairs around the central atom. The molecule shape is expected to be

(a) V-shaped (b) triangular

(c) linear (d) tetrahedral

77. Using VSEPR theory, predict the species which has square pyramidal shape

(a) $SnCl_2$ (b) CCl_4

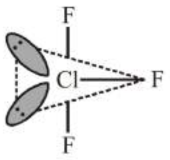
(c) SO_3 (d) BrF_5

78. Among the following molecules : SO_2, SF_4, ClF_3, BrF_5 and XeF_4, which of the following shapes does not describe any of the molecules mentioned?

(a) Bent (b) Trigonal bipyramidal

(c) See-saw (d) T-shape

79. Which of the following structure is most stable ?



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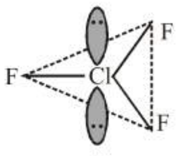

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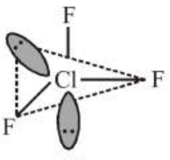


III

Choose the correct option.

(a) Only I

(b) Only II

(c) Only III

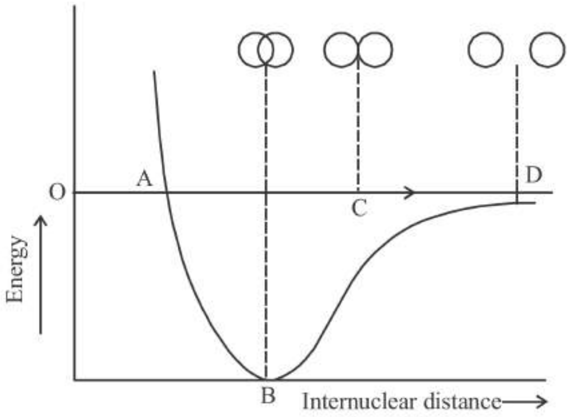
(d) All three have same stability

80. A σ-bonded molecule MX_3 is T-shaped. The number of non-bonding pairs of electron is
(a) 0
(b) 2
(c) 1
(d) can be predicted only if atomic number of M is known.

81. Shape of methane molecule is
(a) tetrahedral (b) pyramidal
(c) octahedral (d) square planar

82. The shape of stannous chloride molecule is
(a) see-saw (b) square planar
(c) trigonal pyramidal (d) bent

83. Look at the following potential energy curve which of the following correctly represents the most stable state of hydrogen molecule.



(a) A (b) B
(c) C (d) D

84. Which of the following statements is false ?
(a) H_2 molecule has one sigma bond
(b) HCl molecule has one sigma bond
(c) Water molecule has two sigma bonds and two lone pairs
(d) Acetylene molecule has three pi bonds and three sigma bonds

85. The number of sigma (σ) and pi (π) bonds present in 1,3,5,7 octatetraene respectively are
(a) 14 and 3 (b) 17 and 4
(c) 16 and 5 (d) 15 and 4

86. Allyl cyanide molecule contains
(a) 9 sigma bonds, 4 pi bonds and no lone pair
(b) 9 sigma bonds, 3 pi bonds and one lone pair
(c) 8 sigma bonds, 5 pi bonds and one lone pair
(d) 8 sigma bonds, 3 pi bonds and two lone pairs

87. The molecule not having π-bond is
(a) Cl_2 (b) O_2
(c) N_2 (d) CO_2

88. In hexa-1, 3-diene-5-yne the number of C — C δ, C — C π and C — H σ bonds, respectively are
(a) 5, 4 and 6 (b) 6, 3 and 5
(c) 5, 3 and 6 (d) 6, 4 and 5

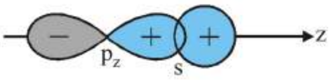
89. The angle between the overlapping of one s-orbital and one p-orbital is
(a) 180° (b) 120°
(c) 109°28' (d) 120° 60'

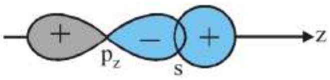
90. The enolic form of a acetone contains
(a) 9 sigma bonds, 1 pi bond and 2 lone pairs
(b) 8 sigma bonds, 2 pi bonds and 2 lone pairs
(c) 10 sigma bonds, 1 pi bond and 1 lone pair
(d) 9 sigma bonds, 2 pi bonds and 1 lone pair

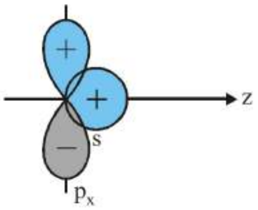
91. Linear combination of two hybridized orbitals belonging to two atoms and each having one electron leads to a
(a) sigma bond
(b) double bond
(c) co-ordinate covalent bond
(d) pi bond.

92. Which of the following statements is not correct ?
(a) Double bond is shorter than a single bond
(b) Sigma bond is weaker than a π (pi) bond
(c) Double bond is stronger than a single bond
(d) Covalent bond is stronger than hydrogen bond

93. Which of the following represents zero overlap of atomic orbitals.

(a)


(b)


(c)


(d) All of these

94. As the s-character of hybridised orbital increases, the bond angle
(a) increase (b) decrease
(c) becomes zero (d) does not change

95. Which of the following is/are not essential condition(s) for hybridisation?
(i) The orbitals present in the valence shell of the atom are hybridised.
(ii) The orbitals undergoing hybridisation should have almost equal energy.
(iii) Promotion of electron is essential prior to hybridisation
(iv) Only half filled orbitals participate in hybridisation.
(a) (i) only (b) (iii) only
(c) (iv) only (d) (iii) and (iv)

96. The nature of hybridisation in the ammonia molecule is

(a) sp^2 (b) dp^2

(c) sp (d) sp^3

97. The shape of sulphate ion is

(a) square planar (b) triagonal

(c) trigonal planar (d) tetrahedral

98. The strength of bonds formed by s–s and p–p, s–p overlap in the order of

(a) s–p > s–s > p–p (b) p–p > s–s > s–p

(c) s–s > p–p > s–p (d) s–s > s–p > p–p

99. Which of the following will have sp^3d^3 hybridisation?

(a) BrF_5 (b) PCl_5

(c) XeF_6 (d) SF_6

100. The shape of CO_2 molecule is

(a) linear (b) tetrahedral

(b) planar (d) pyramidal

101. The hybridisation state of carbon in fullerene is

(a) *sp* (b) sp^2

(c) sp^3 (d) sp^3d

102. Which of the following statements is true for an ion having sp^3 hybridisation?

(a) all bonds are ionic

(b) H-bonds are situated at the corners of a square

(c) all bonds are co-ordinate covalent

(d) H-atoms are situated at the corners of tetrahedron

103. Which of the following molecule does not have a linear arrangement of atoms ?

(a) H_2S (b) C_2H_2

(c) BeH_2 (d) CO_2

104. In which one of the following molecules the central atom said to adopt sp^2 hybridization?

(a) BeF_2 (b) BF_3

(c) C_2H_2 (d) NH_3

105. Considering the state of hybridization of carbon atoms, find out the molecule among the following which is linear ?

(a) $CH_3-CH=CH-CH_3$

(b) $CH_3-C\equiv C-CH_3$

(c) $CH_2=CH-CH_2-C\equiv CH$

(d) $CH_3-CH_2-CH_2-CH_3$

106. Equilateral shape has

(a) *sp* hybridisation (b) sp^2 hybridisation

(c) sp^3 hybridisation (d) None of these

107. In an octahedral structure, the pair of *d* orbitals involved in d^2sp^3 hybridization is

(a) $d_{x^2-y^2}, d_{z^2}$ (b) $d_{xz}, d_{x^2-y^2}$

(c) d_{z^2}, d_{xz} (d) d_{xy}, d_{yz}

108. The trigonal bipyramidal geometry is obtained from the hybridisation

(a) dsp^3 or sp^3d (b) dsp^2 or sp^2d

(c) d^2sp^3 or sp^3d^2 (d) None of these

109. In which of the following species is the underlined carbon having sp^3 - hybridisation ?

(a) $CH_3-\underline{C}OOH$ (b) $CH_3\underline{C}H_2OH$

(c) $CH_3\underline{C}OCH_3$ (d) $CH_2=\underline{C}H-CH_3$

110. A sp^3-hybrid orbital contains

(a) 25% s-character (b) 75% s-character

(c) 50% s-character (d) 25% p-character

111. The types of hybridisation of the five carbon atoms from left to right in the molecule

$CH_3-CH=C=CH-CH_3$ are

(a) $sp^3, sp^2, sp^2, sp^2, sp^3$ (b) $sp^3, sp, sp^2, sp^2, sp^3$

(c) $sp^3, sp^2, sp, sp^2, sp^3$ (d) $sp^3, sp^2, sp^2, sp, sp^3$

112. Pick out the incorrect statement from the following

(a) sp hybrid orbitals are equivalent and are at an angle of 180° with each other

(b) sp^2 hybrid orbitals are equivalent and bond angle between any two of them is 120°

(c) sp^3d^2 hybrid orbitals are equivalent and are oriented towards corners of a regular octahedron

(d) sp^3d^3 hybrid orbitals are not equivalent

113. All carbon atoms are sp^2 hybridised in

(a) 1, 3-butadiene (b) $CH_2=C=CH_2$

(c) cyclohexane (d) 2-butene

114. Which one of the following is not correct in respect of hybridization of orbitals?

(a) The orbitals present in the valence shell only are hybridized

(b) The orbitals undergoing hybridization have almost equal energy

(c) Promotion of electron is not essential condition for hybridization

(d) Pure atomic orbitals are more effective in forming stable bonds than hybrid orbitals

115. Molecular orbital theory was given by

(a) Kossel (b) Mosley

(c) Mulliken (d) Werner

116. Atomic orbital is monocentric while a molecular orbital is polycentric. What is the meaning of above statements?

(a) Electron density in atomic orbital is given by the electron distribution around a nucleus in an atom. While in molecular orbital it is given by the electron distribution around group of nuclei in a molecule.

(b) While an electron in an atomic orbital is influenced by one nucleus, in a molecular orbital it is influenced by two or more nuclei depending upon the number of atoms in the molecule.

(c) The electron in an atomic orbital is present in one nucleus while in molecular orbital electrons are present on more than one nuclei depending upon the number of atoms in the molecule.

(d) All of these

117. With increasing bond order, stability of bond

(a) Remain unaltered (b) Decreases

(c) Increases (d) None of these

118. The given increasing order of energies of various molecular orbitals is not true for which of the following molecule?

$\sigma 1s < \sigma^* 1s < \sigma 2s < \sigma^* 2s < (\pi 2p_x = \pi 2p_y) < \sigma 2p_z < (\pi^* 2p_x = \pi^* 2p_y) < \sigma^* 2p_z$

(a) B_2 (b) C_2
(c) N_2 (d) O_2

119. Which of the following corresponds unstable molecule? Here N_b is number of bonding electrons and N_a is number of antibonding electrons.

(a) $N_b > N_a$ (b) $N_b < N_a$
(c) $N_a = N_b$ (d) Both (b) and (c)

120. If N_x is the number of bonding orbitals of an atom and N_y is the number of antibonding orbitals, then the molecule/atom will be stable if

(a) $N_x > N_y$ (b) $N_x = N_y$
(c) $N_x < N_y$ (d) $N_x \leq N_y$

121. In the molecular orbital diagram for O_2^+ ion, the highest occupied orbital is

(a) σ MO orbital (b) π MO orbital
(c) π* MO orbital (d) σ* MO orbital

122. The theory capable of explaining paramagnetic behaviour of oxygen is

(a) resonance theory
(b) V.S.E.P.R. theory
(c) molecular orbital theory
(d) valence bond energy

123. In an anti-bonding molecular orbital, electron density is minimum

(a) around one atom of the molecule
(b) between the two nuclei of the molecule
(c) at the region away from the nuclei of the molecule
(d) at no place

124. When two atomic orbitals combine, they form

(a) one molecular orbital (b) two molecular orbital
(c) three molecular orbital (d) four molecular orbital

125. Paramagnetism is exhibited by molecules

(a) not attracted into a magnetic field
(b) containing only paired electrons
(c) carrying a positive charge
(d) containing unpaired electrons

126. The difference in energy between the molecular orbital formed and the combining atomic orbitals is called

(a) bond energy (b) activation energy
(c) stabilization energy (d) destabilization energy

127. The bond order in N_2^+ is

(a) 1.5 (b) 3.0
(c) 2.5 (d) 2.0

128. Which molecule has the highest bond order?

(a) N_2 (b) Li_2
(c) He_2 (d) O_2

129. Which one of the following molecules is expected to exhibit diamagnetic behaviour ?

(a) C_2 (b) N_2
(c) O_2 (d) S_2

130. The correct statement with regard to H_2^+ and H_2^- is

(a) both H_2^+ and H_2^- are equally stable
(b) both H_2^+ and H_2^- do not exist
(c) H_2^- is more stable than H_2^+
(d) H_2^+ is more stable than H_2^-

131. Mark the incorrect statement in the following

(a) the bond order in the species O_2, O_2^+ and O_2^- decreases as $O_2^+ > O_2 > O_2^-$
(b) the bond energy in a diatomic molecule always increases when an electron is lost
(c) electrons in antibonding M.O. contribute to repulsion between two atoms.
(d) with increase in bond order, bond length decreases and bond strength increases.

132. According to molecular orbital theory which of the following statement about the magnetic character and bond order is correct regarding O_2^+

(a) Paramagnetic and Bond order $< O_2$
(b) Paramagnetic and Bond order $> O_2$
(c) Diamagnetic and Bond order $< O_2$
(d) Diamagnetic and Bond order $> O_2$

133. Bond order is a concept in the molecular orbital theory. It depends on the number of electrons in the bonding and antibonding orbitals. Which of the following statements is true about it ? The bond order

(a) can have a negative quantity
(b) has always an integral value
(c) can assume any positive or integral or fractional value including zero
(d) is a non-zero quantity

134. Which of the following does not exist on the basis of molecular orbital theory ?

(a) H_2^+ (b) He_2^+
(c) He_2 (d) Li_2

135. The paramagnetic property of the oxygen molecule is due to the presence of unpaired electrons present in

(a) $(\sigma 2p_x)^1$ and $(\sigma^* 2p_x)^1$
(b) $(\sigma 2p_x)^1$ and $(\pi 2p_y)^1$
(c) $(\pi^* 2p_y)^1$ and $(\pi^* 2p_z)^1$
(d) $(\pi^* 2p_x)^1$ and $(\pi^* 2p_z)^1$

136. In which of the following state of compound the magnitude of H-bonding will be maximum and in which case it will be minimum ?

(a) Maximum = Solid, Minimum = Liquid
(b) Maximum = Liquid, Minimum = Gas
(c) Maximum = Solid, Minimum = Gas
(d) Maximum = Gas, Minimum = Solid

137. Which of the following are correctly classified ?

	Intermolecular H-bonding	**Intramolecular H-bonding**
(a)	HF	H_2O
(b)	CH_3OH	HF
(c)	H_2O	*o*-nitrophenol
(d)	HF	*p*-nitrophenol

138. Intramolecular hydrogen bond exists in
(a) *ortho* nitrophenol (b) ethyl alcohol
(c) water (d) diethyl ether

139. The boiling point of *p*-nitrophenol is higher than that of *o*-nitrophenol because
(a) NO_2 group at *p*-position behave in a different way from that at *o*-position.
(b) intramolecular hydrogen bonding exists in *p*-nitrophenol
(c) there is intermolecular hydrogen bonding in *p*-nitrophenol
(d) *p*-nitrophenol has a higher molecular weight than *o*-nitrophenol.

140. Which one of the following is the correct order of interactions ?
(a) Covalent < hydrogen bonding < vander Waals < dipole-dipole
(b) vander Waals < hydrogen bonding < dipole < covalent
(c) vander Waals < dipole-dipole < hydrogen bonding < covalent
(d) Dipole-dipole < vander Waals < hydrogen bonding < covalent.

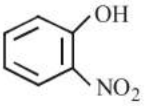
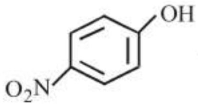
141. Strongest hydrogen bond is shown by
(a) water (b) ammonia
(c) hydrogen fluoride (d) hydrogen sulphide

142. The low density of ice compared to water is due to
(a) induced dipole-induced dipole interactions
(b) dipole-induced dipole interactions
(c) hydrogen bonding interactions
(d) dipole-dipole interactions

143. Methanol and ethanol are miscible in water due to
(a) covalent character
(b) hydrogen bonding character
(c) oxygen bonding character
(d) None of these

144. The hydrogen bond is shortest in
(a) S—H --- S (b) N—H --- O
(c) S—H --- O (d) F—H --- F

145. Hydrogen bonding is maximum in
(a) C_2H_5OH (b) CH_3OCH_3
(c) $(CH_3)_2C=O$ (d) CH_3CHO

146. The vapour pressure of  is higher than  due to
(a) dipole moment (b) dipole-dipole interaction
(c) H-bonding (d) lattice structure

147. The reason for exceptionally high boiling point of water is
(a) its high specific heat
(b) its high dielectric constant
(c) low ionization of water molecule
(d) hydrogen bonding in the molecules of water

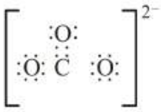
148. Acetic acid exists as dimer in benzene due to
(a) condensation reaction
(b) hydrogen bonding
(c) presence of carboxyl group
(d) presence of hydrogen atom at α-carbon

149. Hydrogen bonding is formed in compounds containing hydrogen and
(a) highly electronegative atoms
(b) highly electropositive atoms
(c) metal atoms with *d*-orbitals occupied
(d) metalloids

STATEMENT TYPE QUESTIONS

150. Read the following statements and choose the correct sequence of T and F from the given codes. Here T represents true and F represents false statement.
(i) The number of dots in Lewis symbol represents the number of valence electrons.
(ii) Number of valence electrons helps to calculate group valence of element.
(iii) Group valence is given as 8 minus the number of inner shell electrons.
(a) T T T (b) T F F
(c) T T F (d) F F F

151. Based on the following Lewis dot structure which of the given statement(s) is/are correct?



(i) There is formation of a double bond and two single bonds.
(ii) There are two additional electrons than those provided by the neutral atoms.
(iii) The least electropositive atom occupies the central position in the molecule/ion.
(a) (i) and (iii) (b) (i), (ii) and (iii)
(c) (iii) only (d) (i) and (ii)

152. Choose the correct sequence of T and F for following statements. Here T stands for true statement and F stands for false statement.

(i) Formal charge in the Lewis structure helps in keeping track of the valence electrons in the molecule.

(ii) Formal charge indicates the actual charge separation within the molecule.

(iii) Formal charges help in the selection of the lowest energy structure from a number of possible Lewis structures.

(a) T T F (b) T F T
(c) T T T (d) F T T

153. Read the following statements and choose the correct option. Here T stands for True and F stands for False statement.

(i) The smaller the size of the cation and the larger the size of the anion, the greater the covalent character of an ionic bond.

(ii) The smaller the charge on the cation, the greater the covalent character of the ionic bond.

(iii) For cations of the same size and charge, the one, with electronic configuration $(n-1)d^n ns^0$, typical of transition metals, is more polarising than the one with a noble gas configuration, $ns^2\ np^6$, typical of alkali and alkaline earth metal cations.

(a) T T T (b) T T F
(c) T F T (d) F T T

154. Choose the correct sequence of T and F for following statements. Here T stands for True and F for False statement.

(i) Sigma bond is formed by head on overlap of bonding orbitals along the internuclear axis.

(ii) Pi bond is formed when atomic orbitals overlap in such a way that their axes remain parallel to each other and perpendicular to the internuclear axis.

(iii) Half-filled *s*-orbital of one atom and half filled *p*-orbitals of another atom forms. π bond on overlapping.

(iv) Overlapping in case of pi-bond takes place to a larger extent as compared to sigma bond.

(a) T T T T (b) T F T F
(c) T T F F (d) T T F T

155. Give the correct order of initials *T* or *F* for following statements. Use *T* if statement is true and *F* if it is false :

(i) The order of repulsion between different pair of electrons is $l_p - l_p > l_p - b_p > b_p - b_p$

(ii) In general, as the number of lone pair of electrons on central atom increases, value of bond angle from normal bond angle also increases

(iii) The number of lone pair on O in H_2O is 2 while on N in NH_3 is 1

(iv) The structures of xenon fluorides and xenon oxyfluorides could not be explained on the basis of VSEPR theory

(a) TTTF (b) TFTF
(c) TFTT (d) TFFF

156. Which of the following statements is/are not correct for combination of atomic orbitals?

(i) The combining atomic orbitals must have the same or nearly the same energy.

(ii) Greater the extent of overlap, the greater will be the electron density between the nuclei of a moleculer orbital.

(iii) $2p_z$ orbital of one atom can combine with either of $2p_x$, $2p_y$ or $2p_z$ orbital of other atom as these orbitals have same energy.

(a) (i) and (ii) (b) (iii) only
(c) (i) only (d) (ii) and (iii)

MATCHING TYPE QUESTIONS

157. Match the columns

	Column-I		**Column-II**
(A)	BeH_2	(p)	Odd electron molecules
(B)	SF_6	(q)	Expanded octet
(C)	NO_2	(r)	Incomplete octet of central atom

(a) A – (p), B – (q), C – (r)
(b) A – (q), B – (r), C – (p)
(c) A – (r), B – (q), C – (p)
(d) A – (r), B – (p), C – (q)

158. Match the columns

	Column-I		**Column-II**
(A)	HCl	(p)	Covalent compound with directional bond
(B)	CO_2	(q)	Ionic compound with non-directional bonds
(C)	NaCl	(r)	Polar molecule
(D)	CCl_4	(s)	Non-polar molecule

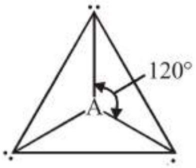
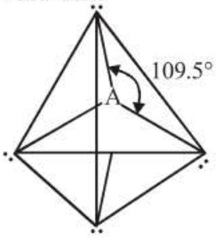
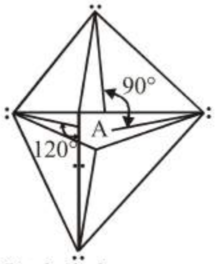
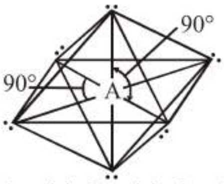
(a) A – (p, q, r), B – (q, r), C – (p, q), D – (r)
(b) A – (q), B – (r), C – (p), D – (s)
(c) A – (p, r), B – (p, s), C – (q), D – (p, s)
(d) A – (q), B – (r), C – (p, q), D – (s)

159. Match Column-I with Column-II and Column-III and choose the correct option from the given codes.

Column-I	**Column-II**	**Column-III**
Molecule	**(No. of lone pairs and bond pairs)**	**(Shape of molecule)**
(A) NH_3	(i) 1, 2	(p) Bent
(B) SO_2	(ii) 1, 4	(q) Trigonal pyramidal
(C) SF_4	(iii) 2, 3	(r) T-shape
(D) ClF_3	(iv) 1, 3	(s) See-Saw

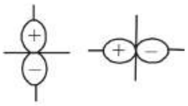
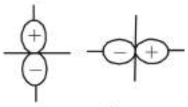
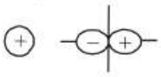
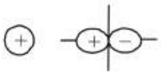
(a) A – (iv, q); B – (ii, p); C – (i, r); D – (iii, s)
(b) A – (iv, q); B – (i, p); C – (ii, s); D – (iii, r)
(c) A – (i, p); B – (iii, s); C – (iv, r); D – (ii, q)
(d) A – (iv, p); B – (i, r); C – (iii, q); D – (ii, s)

160. Match the columns

	Column-I		**Column-II**
(A)	Trigonal planar  	(p)	PCl_5
(B)	Tetrahedral  	(q)	NH_4^+
(C)	Trigonal bipyramidal  	(r)	SF_6
(D)	Octahedral  	(s)	BF_3

(a) A – (p), B – (q), C – (r), D – (s)
(b) A – (s), B – (r), C – (q), D – (p)
(c) A – (s), B – (q), C – (p), D – (r)
(d) A – (r), B – (p), C – (q), D – (s)

161. Match the columns

	Column-I		**Column-II**
(A)	 	(p)	negative overlap
(B)	 	(q)	zero overlap
(C)	 	(r)	positive overlap
(D)	 		

(a) A – (p), B – (q), C – (p), D – (r)
(b) A – (p), B – (r), C – (q), D – (p)
(c) A – (q), B – (q), C – (p), D – (r)
(d) A – (r), B – (p), C – (q), D – (p)

162. Match Column-I (molecule) with Column-II (type of hybridisation) and choose the correct option from the codes given below.

Column-I (Molecule)	**Column-II (Type of hybridisation)**
(A) SF_6	(p) sp^3d
(B) PF_5	(q) sp^3
(C) BCl_3	(r) sp^3d^2
(D) C_2H_6	(s) sp^2

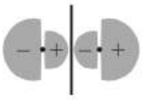
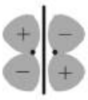
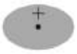
(a) A – (r), B – (p), C – (s), D – (q)
(b) A – (r), B – (p), C – (q), D – (s)
(c) A – (p), B – (r), C – (q), D – (s)
(d) A – (p), B – (r), C – (s), D – (q)

163. Match the columns

Column-I	**Column-II**
(A) Valence bond theory	(p) Nyholm and Gillespie
(B) Octet rule	(q) F. Hund & R. S Mulliken
(C) Molecular orbital theory	(r) Heitler and London
(D) The valence shell electron pair repulsion theory	(s) Kössel and Lewis

(a) A – (p), B – (q),C – (r), D – (s)
(b) A – (q), B – (r),C – (s), D – (p)
(c) A – (p), B – (s),C – (q), D – (r)
(d) A – (s), B – (r), C – (q), D – (p)

164. Match the columns

Column-I	**Column-II**	**Column-III**
(A) 1s	(p)  	(i) 
(B) $2p_z$	(q)  	(ii) 
(C) $2p_x$	(r)  	(iii) 

(a) A – (q, iii), B – (r, i), C – (p, ii)
(b) A – (q, iii), B – (p, ii), C – (r, i)
(c) A – (p, iii), B – (q, ii), C – (r, i)
(d) A – (p, ii), B – (q, iii), C – (r, i)

ASSERTION-REASON TYPE QUESTIONS

Directions : Each of these questions contain two statements, Assertion and Reason. Each of these questions also has four alternative choices, only one of which is the correct answer. You have to select one of the codes (a), (b), (c) and (d) given below.

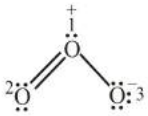
(a) Assertion is correct, reason is correct; reason is a correct explanation for assertion.

(b) Assertion is correct, reason is correct; reason is not a correct explanation for assertion

(c) Assertion is correct, reason is incorrect

(d) Assertion is incorrect, reason is correct.

165. Assertion : The correct Lewis structure of O_3 may be drawn as



Reason : The formal charges on atom 1, 2 and 3 are +1, 0 and –1 respectively.

166. Assertion : Atoms can combine either by transfer of valence of electrons from one atom to another or by sharing of valence electrons.

Reason : Sharing and transfer of valence electrons is done by atoms to have an octet in their valence shell.

167. Assertion : The lesser the lattice enthalpy more stable is the ionic compound.

Reason : The lattice enthalpy is greater, for ions of highest charge and smaller radii.

168. Assertion : Sulphur compounds like SF_6 and H_2SO_4 have 12 valence electrons around S atom.

Reason : All sulphur compounds do not follow octet rule.

169. Assertion : BF_3 molecule has zero dipole moment.

Reason : F is electronegative and B–F bonds are polar in nature.

170. Assertion : CH_2Cl_2 is non-polar and CCl_4 is polar molecule.

Reason : Molecule with zero dipole moment is non-polar in nature.

171. Assertion : Lone pair-lone pair repulsive interactions are greater than lone pair-bond pair and bond pair-bond pair interactions.

Reason : The space occupied by lone pair electrons is more as compared to bond pair electrons.

172. Assertion : In NH_3, N is sp^3 hybridised, but angle is found to be 107°.

Reason : The decrease in bond angle is due to repulsion between the lone pair.

173. Assertion : Shape of NH_3 molecule is tetrahedral.

Reason : In NH_3 nitrogen is sp^3 hybridized.

174. Assertion : pi bonds are weaker than σ bonds.

Reason : pi bonds are formed by the overlapping of p-p orbitals along their axes.

175. Assertion : The bond order of helium is always zero.

Reason : The number of electrons in bonding molecular orbital and antibonding molecular orbital is equal.

176. Assertion : Bonding molecular orbital has greater stability than corresponding antibonding molecular orbital.

Reason : The electron density in a bonding molecular orbital is located away from the space between the nuclei while in antibonding molecular orbital it is located between the nuclei of the bonded atoms.

177. Assertion : Water is one of the best solvent.

Reason : H-bonding is present in water molecules.

CRITICAL THINKING TYPE QUESTIONS

178. What is the correct mode of hybridisation of the central atom in the following compounds?

	NO^-_2	SF_4	PF_6^-
(a)	sp	sp^2	sp^3
(b)	sp^2	sp^3d	sp^3d^2
(c)	sp^2	sp^3	d^2sp^3
(d)	sp^3	sp^3	sp^3d^2

179. Which of the following molecules has trigonal planar geometry?

(a) BF_3 (b) NH_3

(c) PCl_3 (d) IF_3

180. Which of the following molecules is planar?

(a) SF_4 (b) XeF_4

(c) NF_3 (d) SiF_4

181. Hybridization present in ClF_3 is

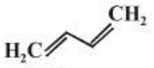
(a) sp^2 (b) sp^3

(c) dsp^2 (d) sp^3d

182. Which of the following represents the given mode of hybridisation sp^2 –sp^2 – sp - sp from left to right ?

(a) $H_2C=CH-C\equiv N$ (b) $HC\equiv C-C\equiv CH$

(c) $H_2C=C=C=CH_2$ (d)



183. Hybridisation states of C in CH_3^+ and CH_4 are

(a) sp^2 & sp^3 (b) sp^3 & sp^2

(c) sp^2 & sp^2 (d) sp^3 & sp^3

184. The type of hybridization in xenon atom and the number of lone pairs present on xenon atom in xenon hexafluoride molecule are respectively

(a) sp^3d^3 , one (b) sp^3d^3 , two

(c) sp^3d^3 , two (d) sp^3d^2 , zero

185. In which of the following species, all the three types of hybrid carbons are present?

(a) $CH_2=C=CH_2$ (b) $CH_3-CH=CH-CH_2^+$

(c) $CH_3-C\equiv C-CH_2^+$ (d) $CH_3-CH=CH-CH_2^-$

186. If an organic compound contain 92.3% C and 7.7% H, than number of sp^3,sp^2 and sp hybridized carbon atoms in all possible structures of compound respectively are (molecular mass = 52g/mol)

(a) 1, 2, 5 (b) 0, 4, 4

(c) 0, 8, 4 (d) None of these

187. Arrange the following in increasing order of bond length

(i) N_2 (ii) N_2^+

(iii) N_2^{2+}

(a) (ii), (i) and (iii) (b) (ii), (iii) and (i)

(c) (iii), (ii) and (i) (d) (i), (ii) and (iii)

188. Which of the following molecule exist ?

(a) He_2 (b) Be_2

(c) Li_2 (d) Both (a) and (b)

189. Hybridization and structure of I^{3-} are

(a) sp^2 and trigonal planar

(b) sp^3d^2 and linear

(c) sp^3d and linear

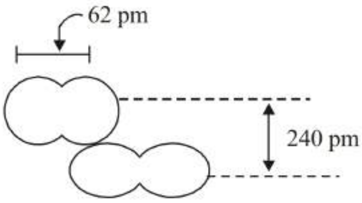
(d) sp^3 and T-shape

190. What is the change in hybridization when $AlCl_3$ changes to $[Al_2Cl_6]^{-3}$?

(a) sp^3d to sp^3d^2 (b) sp^3 to sp^3d

(c) sp^2 to sp^3d^2 (d) None of these

191. From the given figure the van der Waal radius and covalent radius of the hydrogen atom respectively are



(a) 151, 31 (b) 120, 31

(c) 31, 100 (d) 30, 120

192. Which of the following substances has the greatest ionic character ?

(a) Cl_2O (b) NCl_3

(c) $PbCl_2$ (d) $BaCl_2$

193. Among the following species, identify the pair having same bond order CN^-, O_2^-, NO^+, CN^+

(a) CN^- and O_2^- (b) O_2^- and NO^+

(c) CN^- and NO^+ (d) CN^- and CN^+

194. Which of the following is not correct with respect to bond length of the species ?

(a) $C_2 > C_2^{2-}$ (b) $B_2^+ > B_2$

(c) $Li_2^+ > Li_2$ (d) $O_2 > O_2^-$

195. The molecule which has the highest bond order is

(a) C_2 (b) N_2

(c) B_2 (d) O_2

196. The compound which cannot be formed is

(a) He (b) He^+

(c) He_2 (d) He^{+2}

197. The ground state electronic configuration of valence shell electrons in nitrogen molecule (N_2) is written as KK $\sigma 2s^2, \sigma^* 2s^2, \pi 2p_x^2, \pi 2p_y^2 \sigma 2p_z^2$ Bond order in nitrogen molecule is

(a) 0 (b) 1

(c) 2 (d) 3

198. Bond order in benzene is

(a) 1 (b) 2

(c) 1.5 (d) None of these

199. In O_2^- , O_2 and O_2^{-2} molecular species, the total number of antibonding electrons respectively are

(a) 7, 6, 8 (b) 1, 0, 2

(c) 6, 6, 6 (d) 8, 6, 8

200. N_2 and O_2 are converted to monopositive cations N_2^+ and O_2^+ respectively. Which is incorrect ?

(a) In N_2^+ the N–N bond is weakened

(b) In O_2^+ the bond order increases

(c) In O_2^+ the paramagnetism decreases

(d) N_2^+ becomes diamagnetic

201. Bond order normally gives idea of stability of a molecular species. All the molecules viz. H_2, Li_2 and B_2 have the same bond order yet they are not equally stable. Their stability order is

(a) $H_2 > B_2 > Li_2$ (b) $Li_2 > H_2 > B_2$

(c) $Li_2 > B_2 > H_2$ (d) $B_2 > H_2 > Li_2$

202. According to MO theory which of the following lists ranks the nitrogen species in terms of increasing bond order?

(a) $N_2^{2-} < N_2^- < N_2$ (b) $N_2 < N_2^{2-} < N_2^-$

(c) $N_2^- < N_2^{2-} < N_2$ (d) $N_2^- < N_2 < N_2^{2-}$

203. Hydrogen bonding would not affect the boiling point of

(a) HI (b) H_2O

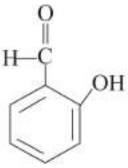
(c) NH_3 (d) CH_3OH

204. Which one of the following molecules will form a linear polymeric structure due to hydrogen bonding?

(a) NH_3 (b) H_2O

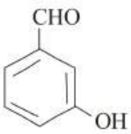
(c) HCl (d) HF

205. Which among the following can form intermolecular H – bonding ?



(A)

(B)



(C)

(D)

(a) A (b) B and D

(c) B, C and D (d) A and C

HINTS AND SOLUTIONS

FACT/DEFINITION TYPE QUESTIONS

1. **(a)** Chemical bond is an attractive force, which holds various constituents (atoms, ions etc.) together in different chemical species.

2. **(d)** The evolution of various theories of valence and the interpretation of the nature of chemical bonds have closely been related to the developments in the understanding of structure of atom, electronic configuration of elements and Periodic Table.

3. **(b)** Kossel and Lewis provide some logical explanation of valence which was based on the intertness of noble gases.

4. **(c)** In the formation of a molecule, only the outer shell electrons take part in chemical combination and they are known as **valence electrons.**

5. **(d)** Valence electrons in O = 6

   ∴ Correct Lewis symbol = $:\ddot{O}:$

   Similarly, Ne is a noble gas having valence electrons = 8

   ∴ Correct Lewis symbol for Ne = $:\ddot{\underset{\cdot\cdot}{N}}e:$

6. **(b)** Electrovalent bond is formed as a result of electrostatic attraction between the positive and negative ions.

7. **(a)** The electrostatic force that binds the oppositely charged ions which are formed by transfer of electron(s) from one atom to another is called ionic bond. Cation and anion are oppositely charged particles therefore they form ionic bond in crystal.

8. **(a)** Calcium is assigned a positive electrovalence of two, while chlorine has a negative electrovalence of one.

9. **(d)** When a metal for example Na combines with a non metal e.g., Cl_2. Following reaction occurs

   $$2Na + Cl_2 \longrightarrow 2NaCl$$

   In this process Na loses one electron to form Na^+ and Cl accepts one electron to form Cl^-

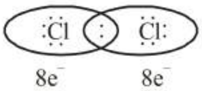
   $$Na \longrightarrow Na^+ + e^-$$
   $$Cl + e^- \longrightarrow Cl^-$$

   Therefore, in this process Cl gain electrons and hence its size increases.

10. **(b)** **Langmuir** (1919) refined the Lewis postulations by abandoning the idea of the stationary cubical arrangement of the octet, and by introducing the term **covalent bond.**

11. **(c)** Each combining atom contributes at least one electron to the shared pair.

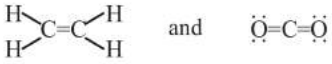
12. **(a)** In formation of Cl_2 molecule a pair of electrons is shared between the two chlorine atoms. Each chlorine atom contribute one electron to the shared pair.



13. **(a)** (i) represents $: N \equiv N :$

    (iv) represents $H - C \equiv C - H$

    (ii) and (iii) represents respectively :



14. **(a)** All Lewis representation of the molecules NH_3, O_3 and HNO_3 given in question are correct.

15. **(c)** N_2 ; $N \equiv N$

    3 electrons are shared by each nitrogen atom

16. **(a)** Lewis structure of N_2 is $\overset{\times\times}{N} \equiv \overset{\times\times}{N}$

17. **(a)** Step I : Skeleton OCO

    Step II : A = 1 × 4 for C + 2 × 6 for O = 4 + 12
    = 16 electrons

    Step III : Total no. of electrons needed to achieve noble gas configuration (N)

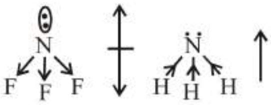
    $N = 1 \times 8 + 2 \times 8 = 24$

    Step IV : Shared electrons, S = N – A = 24 – 16
    = 8 electrons

    Step V : O::C::O

    Step VI : $:\ddot{O}::C::\ddot{O}: \Rightarrow :\ddot{O} = C = \ddot{O}:$

18. **(b)**



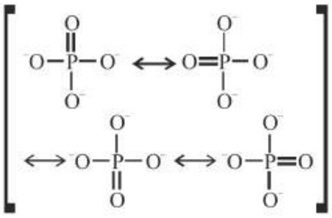
$:N \equiv \overset{+}{N} - \underset{\cdot\cdot}{\ddot{O}}:^{-}$ octet of each atom is complete.

19. **(c)** Formal charge (F.C.) on an atom in a Lewis structure
    = [total number of valence electrons in the free atom]
    – [total number of non bonding (lone pair) electrons]
    – (1/2) [total number of bonding (shared) electrons]

20. **(a)** The lowest energy structure is the one with the smallest formal charges on the atoms.

21. **(c)** Bond order between P – O

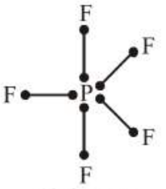
    $$= \frac{\text{no. of bonds in all possible direction}}{\text{total no. of resonating structures}} = \frac{5}{4} = 1.25$$



Formal charge on oxygen = $-\frac{3}{4} = -0.75$

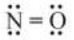
22. **(b)** In CN^- ion formal negative charge is on nitrogen atom due to lone pair of electrons.

23. **(d)** According to octet role, the central atom must have 8 electrons but in some compounds the number of electrons is more than 8, or less than 8 or an odd number of electrons is left on the central atom e.g., PCl_5, BF_5, NO.



10 electrons around P

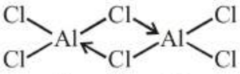
6 electrons around B



Odd electrons around N

24. **(d)**

25. **(c)** (i)



(Complete octet)

(ii)

(3c – 2e) bond
(incomplete octet)

(iii) $\underset{\text{(ionic compound)}}{AlF_3} \longrightarrow \underset{\substack{2s^2 2p^6 \\ \text{(octet complete)}}}{Al^{3+}} + \underset{\substack{2s^2 2p^6 \\ \text{(octet complete)}}}{3F^-}$

(iv)

(Incomplete octet)

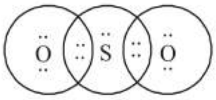
(inomplete octet)

(v)

(Incomplete octet)

$(3c - 2e^-)$ bond

26. **(d)**



Total no. of valence electron around sulphur in SO_2 is 10 while in case of other molecules total no. of 8 electrons are present in each.

27. **(a)** Boron in BCl_3 has 6 electrons in outermost shell. Hence BCl_3 is a electron deficient compound.

28. **(b)** The compounds in which octet of central atom is incomplete are known as electron deficient compounds. Hence B_2H_6 is a electron deficient compound.

29. **(a)** PCl_5 does not follow octet rule, it has 10 electrons in its valence shell.

30. **(a)**

31. **(c)** Formation of positive ion involves removal of electron(s) from neutral atom and that of the negative ion involves addition of electron(s) to the neutral atom.

32. **(b)** Ionic bonds will be formed more easily between elements with comparatively low ionization enthalpies and elements with comparatively high negative value of electron gain enthalpy.

33. **(a)** In ionic solids, the sum of the electron gain enthalpy and the ionization enthalpy may be positive but still the crystal structure gets stabilized due to the energy released in the formation of the crystal lattice.

34. **(d)** Lattice enthalpy is required to completely separate one mole of a solid ionic compound into gaseous constituent ions.

35. **(a)** An ionic bond tightly held the two ions of opposite charges together, so it is a dipole. More is the electronegativity of anion higher will be the electron density and higher will be its charge which consequently increses the strength of ionic bond.

36. **(c)** Higher the difference in electronegativity between the two atoms, more will be electrovalent character of the bond. Among given choices, calcium and hydrogen have maximum difference in their electronegativities.

37. **(b)** For compounds containing cations of same charge, lattice energy increases as the size of the cation decrease. Thus, NaF has highest lattice energy. The size of cations is in the order $Na^+ < K^+ < Rb^+ < Cs^+$

38. **(b)** Ionic character of a bond is directly proportional to the difference of electro negativities of bonded atoms. So, H – F in which electronegativity difference is highest, will have highest ionic character.

39. **(b)** The stability of the ionic bond depends upon the lattice energy which is expected to be more between Mg and F due to +2 charge on Mg atom.

40. **(d)** Bond lengths are measured by spectroscopic, X-ray diffraction and electron diffraction techniques.

41. **(c)** The covalent radius is measured approximately as the radius of an atom's core which is in contact with the core of an adjacent atom in a bonded situation.

42. **(d)** A = Covalent radius
B = van der Waal's radius
C = Bond length

43. **(d)** All of the given statements are correct.

44. **(c)** Bond order $\propto$ bond enthalpy $\propto \dfrac{1}{\text{bond length}}$

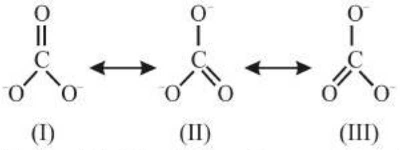
45. **(c)** In CO (three shared election pairs between C and O) the bond order is 3. For N_2 bond order is 3 and its $\Delta_g H^\ominus$ is 946 kJ mol^{-1}, being one of the highest for a diatomic molecule, isoelectronic moleculaes and ions have identical bond order for example F_2 and O_2^{2-} have bond ordeer 1, N_2, CO and NO^+ have bond order 3.

46. **(c)** Both representation of resonating structures in molecules of CO_2 and CO_3^{2-} are correct.

47. **(c)** I and II structure shown above constitute the cannonical structure. III structure represents the structure of O_3 more accurately. This is also called resonance hybrid.

48. **(a)** The molecule does not exist for a certain fraction of time in one cannonical form and for other fractions of time in other cannonical forms.

49. **(b)** There are three resonance structures of CO_3^{2-} ion.



50. **(d)** Choices (a), (b) and (c) are the resonance structures of CO_2.

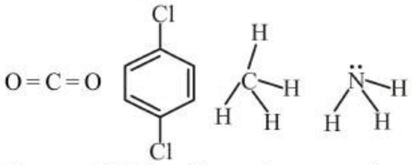
51. **(b)** **52.** **(b)**

53. **(b)** Both NO_2 and O_3 have angular shape and hence will have net dipole moment.

54. **(c)** The dipole moment of symmetrical molecules is zero.

Triangular planar (symmetrical molecule)

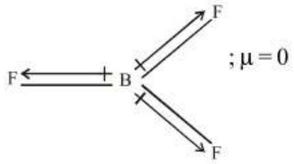
55. **(c)** Dipole moment is a vector quantity, hence the dipole moment of symmetrical molecules is zero. As CO_2, *p*-dichlorobenzene and CH_4 have regular symmetrical shape. Hence $\mu = 0$



However, NH_3 has distorted structure due to presence of lone pair of electrons on N atom and thus has definite dipole moment.

56. **(a)** In H_2, both atoms are identical, so the molecule is non polar.

57. **(b)** BF_3 has planar and symmetrical structure thus as a result the resultant of two bond moments, being equal and opposite to the third, cancels out and hence molecule possess zero dipole moment.



58. **(c)** CCl_4 and BF_3 being symmetrical have zero dipole moment. H_2O, $CHCl_3$ and NH_3 have dipole moments of 1.84 D, 1.01 D and 1.46 D respectively. Thus among the given molecules H_2O has highest dipole moment.

59. **(b)** $O=C=O$

60. **(a)** The correct order of dipole moments of HF, H_2S and H_2O us
$HF < H_2S < H_2O$

61. **(a)** $\overset{\delta+}{C} - \overset{\delta-}{F}$

Because difference between electronegativity of carbon and flourine is highest.

62. **(c)** In case of SF_6 resultant dipole moment is zero while all other possess dipole moment.

63. **(c)**

64. **(c)** According to Fajan's rule, smaller size and greater charge on cation favour the formation of partial covalent character in ionic bonds.

65. **(c)** As difference of electronegativity increases % ionic character increases and covalent character decreases i.e., electronegativity difference decreases covalent character increases.

Further greater the charge on the cation and smaller the size more will be its polarising power. Hence covalent character increases.

66. **(a)** According to Fajan's rule, as the charge on the cation increases, and size decreases, its tendency to polarise the anion increases. This brings more and more covalent nature to electrovalent compounds. Hence $AlCl_3$ shows maximum covalent character.

67. **(d)** In case of anions having same charge as the size of anion increases, polarisibility of anion also increases.

68. **(d)** The electronegativity difference is maximum in O—H bond hence O—H bond length is the smallest among the given set.

69. **(a)** A gaseous HCl molecule has hydrogen and chlorine linked by a covalent bond. Here electronegativity of chlorine is greater than that of hydrogen. Due to this the shared pair of electron is more attracted towards chlorine. Thus, chlorine end of molecule has higher electron density and becomes slightly negative and the hydrogen and slightly positive. Hence the covalent bond in HCl has a polar character as shown below

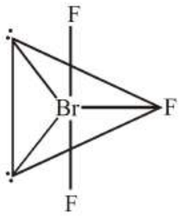
$$\overset{\delta^+}{H} \longrightarrow \overset{\delta^-}{Cl}$$

70. **(b)** Hydrogen is non metal and non metal atoms form covalent bond.

71. **(d)**

72. **(b)** Hybridisation is sp^3 and shape pyramidal.

73. **(c)**



In BrF_3, both bond pairs as well as lone pairs of electrons are present. Due to the presence of lone pairs of electrons (lp) in the valence shell, the bond angle is contracted and the molecule takes the T-shape. This is due to greater repulsion between two lone pairs or between a lone pair and a bond pair than between the two bond pairs.

74. **(a)** The number of lone pairs of electrons on central atom in various given species are

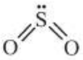
Species	Number of lone pairs on central atom
IF_7	nil
IF_5	1
ClF_3	2
XeF_2	3

Thus the correct increasing order is

$IF_7 < IF_5 < ClF_3 < XeF_2$

0 1 2 3

75. **(d)**



lp = 1

bp = 4

76. **(a)** V-shaped H_2O like structure.

77. **(d)** BrF_5 has square pyramidal geometry.

78. **(b)** SO_2 – bent

SF_4 – see-saw

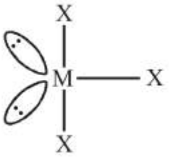
ClF_3 – T-shape

BrF_5 – square pyramidal

XeF_4 – square planar.

79. **(a)** I is the most stable geometry because both the lone pairs are present at equitorial position. Due to which repulsion is minimum in molecule as compared to the repulsion in other molecules where lone pair is in axial position.

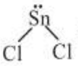
80. **(b)**



Number of lone pair = 2

81. **(a)** In methane molecule C is sp^3 hybridised so its shape will be tetrahedral.

82. **(d)**



Bent

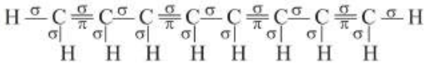
83. **(b)** The minimum in the energy curve corresponds to the most stable state of H_2.

84. **(d)** Structure of acetylene molecule

$$H\overset{1\sigma}{—}C\underset{2\pi}{\overset{1\sigma}{\equiv}}C\overset{1\sigma}{—}H$$

Thus acetylene molecule has 3σ bonds and 2π bonds.

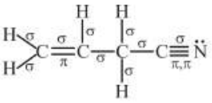
85. **(b)**



1, 3,5, 7 - octatetraene

17 σ and 4π

86. **(b)** Allyl cyanide is :



$\therefore$ It contains 9 sigma bonds, 3 pi bonds and 1 lone pair of electrons.

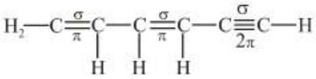
87. **(a)** Cl_2 : $Cl - Cl\ (1\sigma, \text{No } \pi)$

O_2 : $O = O\ (1\sigma, 1\pi)$

N_2 : $N \equiv N\ (1\sigma, 2\pi)$

CO_2 : $O = C = O\ (2\sigma, 2\pi)$

88. **(a)** The given molecule is

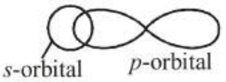


The number of C—C 'σ' bonds = 5

The number of C—C 'π' bonds = 4

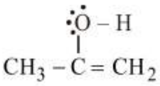
The number of C—C 'σ' bonds = 6

89. **(a)**



The overlap between *s*- and *p*-orbitals occurs along internuclear axis and hence the angle is 180°.

90. **(a)**



$$CH_3 - \overset{\overset{\ddot{O}-H}{|}}{C} = CH_2$$ has $9\sigma, 1\pi$ and 2 lone pairs.

91. **(a)** Linear combination of two hybridized orbitals leads to the formation of sigma bond.

92. **(b)** Sigma bond is stronger than π-bond. The electrons in the π bond are loosely held. The bond is easily broken and is more reactive than σ -bond. Energy released during sigma bond formation is always more than π bond because of greater extent of overlapping

93. **(c)** Option (c) represents zero overlapping.

94. **(a)** Bond angle increases with increase in s-character of hybridised orbital. The table given below shows the hybridised orbitals, their % s-chatracter and bond angles.

Hybridised orbitals	% s-character	Bond angle
sp^3	25	109.5°
sp^2	33	120°
sp	50	180°

95. **(d)** Promotion of electron is not an essential condition prior to hybridisation. It is not necessary that only half filled orbitals participate in hybridisation. In some cases, even filled orbitals of valence shell take part in hybridisation.

96. **(d)** The hybridisation in a molecule is given by

$$H=\frac{1}{2}[V+M-C+A] \quad ....(1)$$

where V = no. of valency e^- in central atom
M = no. of monovalent atoms around central atom
C = charge on cation, A = charge on anion
For NH_3; V = 5, M = 3, C = 0, A = 0
Putting these values in (1), we get

$$H=\frac{1}{2}[5+3-0+0]=4$$

For H = 4, the hybridisation in molecule is sp^3.

97. **(d)** Hybridisaiton of SO_4^{2-} ion is given by

$$H=\frac{1}{2}[V+M+A-C]$$

Where V = valency of central metal atom
M = no. of monovalent atoms surrounding central metal atom.
A = charge on anion, C = charge on cation

For SO_4^{2-}; V = 6, M = 0, A = 2, C = 0

$$\therefore\ H=\frac{1}{2}[6+0+2-0]=4$$

i.e., sp^3 hybridisation and tetrahedral shape.

98. **(d)** The strength of a bond depends upon the extent of overlapping. s-s and s-p overlapping results in the formation of σ bond but extent of overlapping along internuclear axis is more in case of s-s overlapping than in s-p. p-p overlapping may result in σ bond if overlapping takes place along internuclear axis or may result in π–bond if sideways overlapping takes place. In any case the extent of overlapping is lesser in p - p than that of the other two, s-s and s-p. Hence the correct order is

$$s\text{-}s > s\text{-}p > p\text{-}p.$$

99. **(c)** In case of Xenon compounds

Hybridization $=\frac{1}{2}$[No. of valence electrons of Xe + number of monovalent atoms surrounding Xe – charge on cation + charge or an ion]

In $XeF_6=\frac{1}{2}[8+6-0+0]=7$ i.e. sp^3d^3 hybridizaiton.

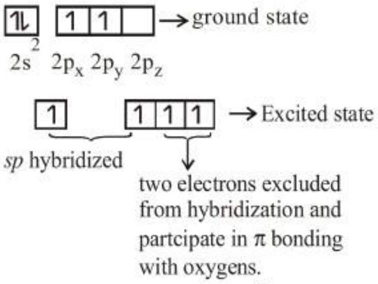
In case of SF_6, Sulphur is **sp^3d^2** hybridized.

In case of BrF_5.Bromine atom has seven valence electrons and 5 are contributed by the fluorine atoms.

∴ Total number of electron pairs in valence shell of central atom $=\frac{7+5}{2}=6$

Number of shared pairs = 5
Number of one pairs = 1
The molecule is **square pyramidal.**
In PCl_5 P is **sp^3d** hybridised. i.e. the correct answer is XeF_6 or option (c)

100. **(a)** $O=C=O$
$C(6)=1s^2\,2s^2\,2p^2$



101. **(b)** In fullerene, carbons are sp^2-hybridised like graphite. Fullerenes are also the allotropes of carbon other than diamond and graphite but have been produced synthetically, e.g.; C_{60}.

102. **(d)** Ions having sp^3 hybridisation contain hydrogen atoms at the corners of tetrahedron.

103. **(a)** For linear arrangement of atoms the hybridisation should be sp(linear shape, 180° angle). Only H_2S has sp^3-hybridization and hence has angular shape while C_2H_2, BeH_2 and CO_2 all involve sp - hybridization and hence have linear arrangement of atoms.

104. **(b)** BF_3 involves sp^2-hybridization.

105. **(b)** $\overset{sp^3}{H_3C}-\overset{sp}{C}\equiv\overset{sp}{C}-\overset{sp^3}{CH_3}$
linear

106. **(b)** Equilateral or triangular planar shape involves sp^2 hybridization.

107. **(a)** Only those *d* orbitals whose lobes are directed along X, Y and Z directions hybridise with *s* and *p* orbitals. In other three *d* orbitals namely d_{xy}, d_{yz} and d_{xz}, the lobes are at an angle of 45° from both axis, hence the extent of their overlap with *s* and *p* orbitals is much lesser than $d_{x^2-y^2}$ and d_{z^2} orbitals.

108. **(a)** According to VSEPR theory, trigonal bipyramidal geometry results from sp^3d or dsp^3 hybridisation. dsp^2 hybridisation results in square planar geometry, while d^2sp^3 leads to octahedral shape.

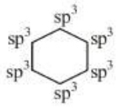
109. **(b)** In $CH_3\,CH_2OH$ underlined C is forming 4 σ bonds, hence sp^3 hybridisation. In others it is sp^2 hybridised (due to 3 σ bonds).

110. **(a)** Each sp^3-hybrid orbital has 25% s-character and 75% p-character.

111. **(c)** $\underset{sp^3}{H_3C}-\underset{sp^2}{CH}=\underset{sp}{C}=\underset{sp^2}{CH}-\underset{sp^3}{CH_3}$

112. **(d)**

113. **(a)** $\overset{sp^2}{CH_2}=\overset{sp}{C}=\overset{sp^2}{CH_2}$



$$\overset{sp^3}{CH_3}-\overset{sp^2}{CH}=\overset{sp^2}{CH}-\overset{sp^3}{CH_3}$$

$$\overset{sp}{HC}\equiv\overset{sp}{C}-\overset{sp}{C}\equiv\overset{sp}{CH}$$

$$\overset{sp^2}{CH_2}=\underset{\text{1, 3-butadiene}}{\overset{sp^2}{CH}-\overset{sp^2}{CH}}=\overset{sp^2}{CH_2}$$

114. (d) Statement (d) is incorrect.

115. (c) Molecular orbital theory was given by Mulliken.

116. (b) Atomic orbital is monocentric because an electron in it is influenced by one nucleus. While molecular orbital is polycentric as it is influenced by two or more nuclei depending upon the number of atoms in the molecule.

117. (c)

118. (d) For oxygen correct increasing order is $\sigma 1s < \sigma{*}1s < \sigma 2s < \sigma{*}2s < \sigma 2p_z < (\pi 2p_x = \pi 2p_y) < (\pi{*}2p_x = \pi{*}2p_y) < \sigma{*}2p_z$

119. (d) $N_b < N_a$ or $N_a = N_b$

i.e., a negative or zero bond order corresponds to an unstable molecule.

120. (a) **121. (c)**

122. (c) Paramagnetism of O_2 is best explained by molecular orbital theory.

123. (b)

124. (b) One bonding M.O. and one anti-bonding M.O.

125. (d) Molecules having unpaired electrons show paramagnetism.

126. (c)

127. (c) $N_2{}^{+} = 7 + 7 - 1 = 13$ electrons

Configuration is

$\sigma 1s^2, \sigma{*}1s^2, \sigma 2s^2, \sigma{*}2s^2, \pi 2p_x{}^2$

$= \pi 2p_y{}^2, \sigma 2p_z^1$

Bond order =

$$\frac{1}{2}\begin{pmatrix}\text{No. of } e^-s \text{ in bonding} & - & \text{No. of } e^-s \text{ in antibonding} \\ \text{molecular orbital} & & \text{molecular orbital}\end{pmatrix}$$

$$= \frac{1}{2}(9-4) = \frac{1}{2}\times 5 = 2.5$$

128. (a)

129. (a, b) The molecular orbital structures of C_2 and N_2 are

$N_2 = \sigma 1s^2\,\sigma{*}1s^2\,\sigma 2s^2\,\sigma{*}2s^2\,\sigma 2p_x^2 \pi 2p_y^2 \pi 2p_z^2$

$C_2 = \sigma 1s^2\,\sigma{*}1s^2\,\sigma 2s^2\,\sigma{*}2s^2 \pi 2py^2 \pi 2P_z^2$

Both N_2 and C_2 have paired electrons, hence they are diamagnetic.

130. (d) $H_2^+ : (\sigma\, 1s^1)$

Bond order $= \frac{1}{2}(1-0) = \frac{1}{2}$

$H_2^- : (\sigma 1s^2)\,(\sigma^* 1s^1)$

Bond order $= \frac{1}{2}(2-1) = \frac{1}{2}$

The bond order of H_2^+ and H_2^- are same but H_2^+ is more stable than H_2^-. In H_2^- the antibonding orbital is filled with 1 electron so this causes instability.

131. (b) The removal of an electron from a diatomic molecule may increase the bond order as in the conversion $O_2\,(2) \longrightarrow O_2^+(2.5)$ or decrease the bond order as in the conversion, $N_2(3.0) \longrightarrow N_2^+(2.5)$, As a result, the bond energy may increase or decrease. Thus, statement (b) is incorrect.

132. (b) $O_2 : \sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \sigma 2p_z^2,$

$$\begin{cases}\pi 2p_x^2 \\ \pi 2p_y^2\end{cases}, \begin{cases}\pi^* 2p_x^1 \\ \pi^* 2p_y^1\end{cases}$$

Bond order $= \dfrac{10-6}{2} = 2$

(two unpaired electrons in antibonding molecular orbital)

$$O_2^+ : \sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \sigma 2p_z^2, \begin{cases}\pi 2p_x^2, \\ \pi 2p_y^2,\end{cases} \begin{cases}\pi^* 2p_x^1 \\ \pi^* 2p_y^0\end{cases}$$

Bond order $= \dfrac{10-5}{2} = 2.5$

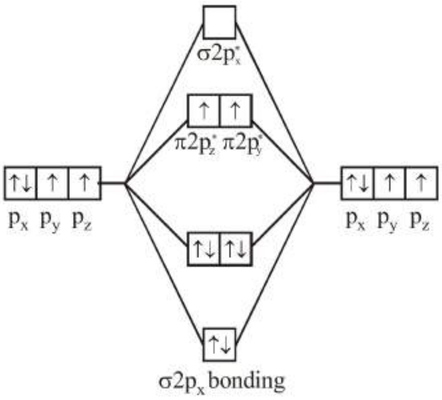
(One unpaired electron in antibonding molecular orbital)

Hence O_2 as well as O_2^+ both are paramagnetic, and bond order of O_2^+ is greater than that of O_2.

133. (c)

134. (c) Helium molecule does not exist as bond order of $He_2 = 0$.

135. (c) The paramagnetic property in oxygen came through unpaired electron which can be explained by molecular orbital theory.

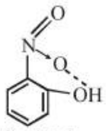


So 2 unpaired of electron present in $\pi 2p_y^*$ and $\pi 2p_z^*$

136. (c) H-bonding is maximum in the solid state and minimum in gaseous state.

137. (c) H_2O shows intermolecular hydrogen bonding while o-nitrophenol shows intramolecular H-bonding.

138. (a)



(Intermolecular hydrogen bonding)

o-nitrophenol

139. (c) The b.p. of p-nitrophenol is higher than that of o-nitrophenol because in p-nitrophenol there is intermolecular H-bonding but in o-nitrophenol it is intramolecular H-bonding.

140. (b) The strength of the interactions follows the order vander Waal's < hydrogen – bonding < dipole-dipole < covalent.

141. (c) H–F shows strongest H-bonds due to high electronegativity of F atom.

142. (c) Ice has many hydrogen bonds which give rise to cage like structure of water molecules. This, structure possess larger volume and thus makes the density of ice low.

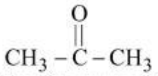
143. (b) Methanol and ethanol are soluble because of the hydrogen bonding.

144. (d) F—H----F bond is shortest, because with the increase of electronegativity and decrease in size of the atom to which hydrogen is linked, the strength of the hydrogen bond increases.

145. (a) Hydrogen bonding is possible only in compounds having hydrogen attached with F, O or N.

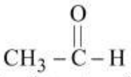
C_2H_5-OH (H-bonding possible)

CH_3-O-CH_3 (H-bonding not possible)



$CH_3-\overset{O}{\overset{||}{C}}-CH_3$

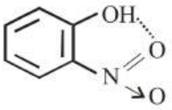
(H-bonding not possible)



$CH_3-\overset{O}{\overset{||}{C}}-H$

(H-bonding not possible)

146. (c) *ortho*-Nitrophenol has intramolecular H-bonding



and *para*-nitrophenol has intermolecular H-bonding.

147. (d) Hydrogen bonding increases the boiling point of compound.

148. (b)

149. (a) Hydrogen bond is formed when hydrogen is attached with the atom which is highly electronegative and having small radius.

STATEMENT TYPE QUESTIONS

150. (c) The group valence of the elements is generally either equal to the number of dots in Lewis symbols or 8 minus the number of dots or valence electrons.

151. (d) The least electronegative atom occupies the central position in the molecule/ion.

152. (b) Formal charges do not indicate real charge separation within the molecule. Indicating the charges on the atoms in the Lewis structure only helps in keeping track of the valence electrons in the molecule.

153. (c) The greater the charge on the cation, the greater the covalent character of the ionic bond.

154. (d) Statement (c) and (d) are incorrect.

155. (b) (ii) (*F*) In general as the number of lone pair of electrons on central atom increases, value of bond angle from normal bond angle decreases due to lp – lp > lp – bp.

(iv)(*F*) Structures of xenon fluorides and xenon oxyfluoride are explained on the basis of VSEPR theory.

In $SOBr_2$, S – O bond has minimum bond length in comparison to S – O bond lengths in SOF_2 and $SOCl_2$, because in $SOBr_2$, S – O bond has been formed by hybrid orbital containing less *s*-character.

156. (b) Atomic orbitals having same or nearly same energy will not combine if they do not have the same symmetry. $2p_z$ orbital of one atom cannot combine with $2p_x$ or $2p_y$ orbital of other atom because of their different symmetries.

MATCHING TYPE QUESTIONS

157. (c) BeH_2 : Incomplete octet of central atom.
Be has 2 valence electrons
SF_6 : Expanded octet
There are 12 electrons around the S atom in SF_6
NO_2 : Odd electron molecules.
In molecules with an odd number of electrons like NO_2, the octet rule is not satisfied.

158. (c)

159. (b) $NH_3 \rightarrow$ 1lp, 3bp $\rightarrow$ Trigonal pyramidal
$SO_2 \rightarrow$ 1lp, 2bp $\rightarrow$ Bent
$SF_4 \rightarrow$ 1lp, 4bp $\rightarrow$ See-saw
$ClF_3 \rightarrow$ 2lp, 3bp $\rightarrow$ T-shape

160. (c) Trigonal planar = BF_3
Tetrahedral = NH_4^+
Trigonal bipyramidal = PCl_5
Octahedral = SF_6

161. (c)

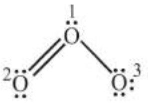
162. (a) $SF_6 \Rightarrow sp^3d^2$
$PF_5 \Rightarrow sp^3d$
$BCl_3 \Rightarrow sp^2$
$C_2H_6 \Rightarrow sp^3$

163. (c) Valence bond theory = Heitler and London
Octet rule = Kössel and Lewis
Molecular orbital theory = F. Hund and R.S. Mulliken
VSEPR theory = Nyholm and Gillespie

164. (b)

ASSERTION-REASON TYPE QUESTIONS

165. (a)

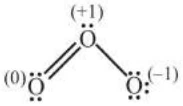


Formal charge on $O_1 = 6 - 2 - \frac{1}{2}(6) = +1$

Formal charge on $O_2 = 6 - 4 - \frac{1}{2}(4) = 0$

Formal charge on $O_3 = 6 - 6 - \frac{1}{2} \times 3 = -1$

Hence, correct representation of O_3 is



166. (a) Atoms combine either by transfer of valence electrons from one atom to another or by sharing of valence electrons to have an octet in their valence shell.

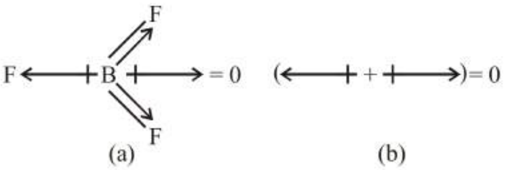
167. (d) Assertion is false but reason is true.

The greater the lattice enthalpy, more stable is the ionic compound.

168. (c) Sulphur forms many compounds in which the octet rule is obeyed. For example SCl_2 has an octet of electrons around it.

169. (b) Both assertion and reason are true but reason is not the correct explanation of assertion.

BF_3 is sp^2 hybridized. Dipole moment is a vector quantity. The three bond moments give a net sum of zero, as the resultant of any two is equal and opposite to the third.



(a) (b)

170. (d) Assertion is false but reason is true.

CH_2Cl_2 is polar while CCl_4 is non-polar because in CCl_4 net dipole moment cancels.

171. (a) While the lone pairs are localised on the central atom, each bonded pair is shared between two atoms. As a result, the lone pair electrons in a molecule occupy more space as compared to the bonding pairs of electrons. This results in greater repulsion between lone pairs of electrons as compared to the lone pair -bond pair and bond pair - bond pair repulsions.

172. (a) Both assertion and reason are true and reason is the correct explanation of assertion.

lone pair – lone pair repulsion > lone pair – bond pair repulsion > bond pair – bond pair repulsion. In the ammonia molecule, NH_3 there are three bond pairs and one lone pair. The three N – H bond pairs are pushed closer because of the lone pair – bond pair repulsion, and HNH bond angle gets reduced from 109°23' (the tetrahedral angle) to 107°.

173. (d) Assertion is false but reason is true.

NH_3 molecule is pyramidal is shape, because out of four electron pairs, three are bonding pairs and one is lone pair.

174. (a) Both assertion and reason are true and reason is the correct explanation of assertion.

pi bonds are formed by the overlapping of p-p orbitals perpendicular to their axis i.e., sidewise overlap.

175. (a) Both assertion and reason are true and reason is the correct explanation of assertion.

Helium molecule is formed by linking two helium atoms. Both have 1s orbitals. These will combine to form two molecular orbitals σ (1s) and σ^* (1s). Four available electrons are accommodated as $\sigma(1s)^2$ and $\sigma^*(1s)^2$.

176. (c) The electron density in a bonding molecular orbital is located between the nuclei of the bonded atoms because of which the repulsion between the nuclei is very less while in case of an antibonding molecular orbital, most of the electron density is located away from the space between the nuclei. Electrons placed in a bonding molecular orbital tend to hold the nuclei together and stabilise a molecule.

177. (b) Both assertion and reason are true but reason is not the correct explanation of assertion.

Water is excellent solvent because it has high value of dielectric constant. Due to high value of dielectric constant, the electrostatic force of attraction between the ions decrease and these ions get separated and ultimately get solvated by the solvent molecules.

CRITICAL THINKING TYPE QUESTIONS

178. (b) Hybridisation of the central atom in compound is given by

$$H = \frac{1}{2}[V + M - C + A]$$

where V = No. of valency electrons in central metal atom,

M = No. of monovalent atoms surrounding the central atom,

C = charge on cation and A = charge on anion

- For NO_2^-, $H = \frac{1}{2}[5 + 0 - 0 + 1] = 3$

  sp^2 hybridisation

- For SF_4, $H=\frac{1}{2}[6+4-0+0]=5$

  sp^3d hybridisation

- For PF_6^-, $H=\frac{1}{2}[5+6-0+1]=6$

  sp^3d^2 hybridisation.

So, option (a) is correct choice.

179. (a) BF_3 is sp^2 hybridised. So, it is trigonal planner. NH_3, PCl_3 has sp^3 hybridisation hence has trigonal bipyramidal shape, IF_3, has sp^3d hydridization and has linear shape.

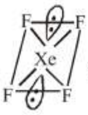
180. (b) XeF_4 hybridisation is $=\frac{1}{2}(V+X-C+A)$

hence V = 8 (no. of valence e^-)

$X = 4$ (no. of monovalent atom)

$$\frac{1}{2}(8+4+0-0)=6 \quad sp^3d^2$$

C = 0 charge on cation

A = 0 (charge on anion). The shape is  square planar shape.

181. (d) Hybridisation present in a molecule can be find out by the following formula.

$$H=\frac{1}{2}(V+M-C+A)$$

Where V = No. of electrons in valence shell of central atom

M = No. of singly charged atoms

C = charge on cation

A = charge on anion

So, Hybridisation (in ClF_3) $=\frac{1}{2}[7+3-0+0]=5$

$\Rightarrow$ sp^3d Hybridisation

182. (a) $\underset{1}{CH_2}=\underset{2}{C}H-\underset{3}{C}\equiv\underset{4}{N}$

3 σ bonds (sp^2 hybridisation); 2 σ bonds (sp - hybridisation)

$C_1 = 3$ σ bonds, $C_2 = 3$ σ bonds,

$C_3 = 2$ σ bonds

183. (a) Hybridisation of carbon in CH_3^+ is sp^2 and in CH_4 its hybridisation is sp^3

184. (a) XeF_4 having one lone pair of electron show distorted pentagonal bipyramidal shape and sp^3d^3 hybridisation.

185. (c) (a) $\underset{sp^2}{CH_2}=\underset{sp}{C}=\underset{sp^2}{CH_2}$

(b) $\underset{sp^3}{CH_3}-\underset{sp^2}{CH}=\underset{sp^2}{CH}-\underset{sp^2}{CH_2^+}$

(c) $\underset{sp^3}{CH_3}-\underset{sp}{C}\equiv\underset{sp}{C}-\underset{sp^2}{CH_2^+}$

(d) $\underset{sp^3}{CH_3}-\underset{sp^2}{CH}=\underset{sp^2}{CH}-\underset{sp^3}{CH_2^-}$

Note : Carbocations and carboanions are sp^2 and sp^3 hybridised respectively.

186. (c) Let amount of compound = 100 g

No. of moles of C $=\frac{92.3}{12}=7.69=7.7$

No. of moles of H $=\frac{7.7}{1}=7.7$

Empirical formula = CH

Empirical formula mass = 12 + 1 = 13 g/mol

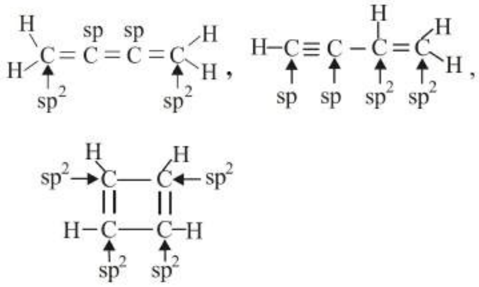
Molecular mass = 52 g/mol

$$n=\frac{52}{13}=4$$

∴ Molecular foumula = Empirical formula × 4

$= C_4H_4$

Possible structures



187. (d) As the bond order decreases, bond length increases

Bond order

$$=\frac{\text{No. of bonding } e^-\text{s} - \text{No. of antibonding } e^-\text{s}}{2}$$

For N_2, electronic configuration is

$$\sigma 1s^2<\sigma^*1s^2<\sigma 2s^2<\sigma^*2s^2<(\pi 2p_x^2=\pi 2p_y^2)<2p_z^2$$

(i) Bond order of $N_2=\frac{10-4}{2}=3$

(ii) Bond order of $N_2^+=\frac{9-4}{2}=2.5$

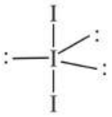
(iii) Bond order of $N_2^{2+}=\frac{8-4}{2}=2$

Hence, order of Bond length will be,

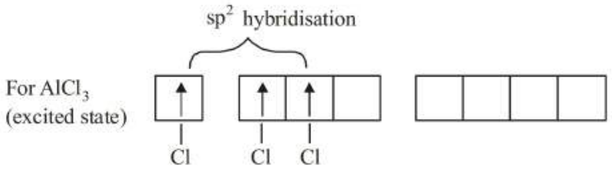
$$N_2<N_2^+<N_2^+$$

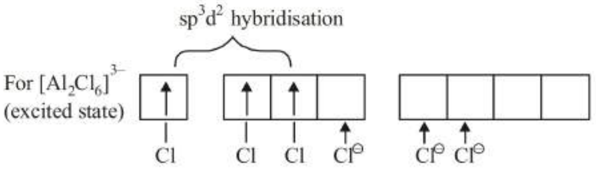
188. (c) According to molecular orbital theory, bond order of Li_2 is 1 , while in all other cases bond order is 0, so they do not exist. Li_2 molecules are known to exist in the vapour phase.

189. (c) I_3^- has sp^3d hybridisation and has linear structure



190. (c)





191. (b) Covalent radius is half of the distance between atoms in bonding state, while van der Waal radius is half of the distance between atoms in its non bonding state.

192. (d) According to Fajan's rule :

$$\text{Covalent character} \propto \frac{1}{\text{size of cation}}$$

$$\propto \text{size of anion}$$

Among the given species order of size of cations

$N^{3+} < O^{2+} < Pb^{2+} < Ba^{2+}$

order of size of anions $O^{2-} > Cl^-$.

Hence the order of covalent character is

$NCl_3 > Cl_2O > PbCl_2 > BaCl_2$

$BaCl_2$ is most ionic in nature.

193. (c) M.O. electronic configuration of CN^- is $\sigma 1s^2\ \sigma^*1s^2\ \sigma 2s^2\ \sigma^*2s^2 \pi 2p_x{}^2\ \pi 2p_y{}^2\ \sigma 2p_z{}^2$

$$\therefore \text{B.O.} = \frac{10-4}{2} = 3$$

M.O. electronic configuration of O_2^- is

$\sigma 1s^2\ \sigma^*1s^2 \sigma 2s^2 \sigma^* 2s^2 \sigma 2p_z{}^2 \pi 2p_x{}^2$
$\pi 2p_y{}^2\ \pi^*2p_x{}^2 \pi^*2p_y{}^1$

$$\therefore \text{B.O.} = \frac{10-7}{2} = 1.5$$

M.O. electronic configuration of CN^+

$\sigma 1s^2\ \sigma^*1s^2\ \sigma 2s^2\ \sigma^*2s^2 \pi 2p_x{}^2\ \pi 2p_y{}^2\ \sigma 2p_z{}^1$

$$\therefore \text{B.O.} = \frac{9-4}{2} = 2.5$$

M.O. electronic configuration of NO^+ is

$\sigma 1s^2\ \sigma^*1s^2\ \sigma 2s^2\ \sigma^*2s^2 \sigma 2p_z{}^2\ \pi 2p_x{}^2\ \pi 2p_y{}^2$

$$\therefore \text{B.O.} = \frac{10-4}{2} = 2$$

$\therefore$ CN^- and NO^+ have bond order equal to 3

194. (d) On calculating bond order of species given in question

$C_2 = 2 \quad C_2^{2-} = 3$

$B_2^+ = 0.5 \qquad B_2 = 1$

$Li_2^+ = 0.5 \qquad Li_2 = 1$

$N_2^+ = 2.5 \qquad N_2 = 3$

$O_2 = 2.0 \qquad O_2^- = 1.5$

$$\text{Bond length} \propto \frac{1}{\text{Bond order}}$$

$\therefore\ O_2^- > O_2$

195. (b) For C_2 (12) :

$(\sigma 1s)^2 (\sigma^* 1s)^2 (\sigma 2s)^2 (\sigma^* 2s)^2 (\pi 2p_x)^2 (\pi 2p_y)^2$

$$\text{B.O.} = \frac{8-4}{2} = 2$$

For N_2(14) :

$(\sigma 1s)^2 (\sigma^* 1s)^2 (\sigma 2s)^2 (\sigma^* 2s)^2 (\pi 2p_x)^2 (\pi 2p_y)^2 (\sigma 2p_z)^2$

$$\therefore \text{B.O.} = \frac{10-4}{2} = 3$$

For B_2 (10)

$= (\sigma 1s)^2\ (\sigma^* 1s)^2 (\sigma 2s)^2 (\sigma^* 2s)^2 (\pi 2p_x)^1 (\pi 2p_y)^1$

$$\therefore \text{B.O.} = \frac{6-4}{2} = 1$$

For O_2 (16)

$= (\sigma 1s)^2\ (\sigma^* 1s)^2 (\sigma 2s)^2 (\sigma^* 2s)^2 (\sigma 2p_z)^2 (\pi 2p_x)^2$
$(\pi 2p_y)^2 (\pi^* 2p_x)^1 (\pi^* 2p_y)^1$

$$\therefore \text{B.O.} = \frac{10-6}{2} = 2$$

F_2 is (18)

$= (\sigma 1s)^2\ (\sigma^* 1s)^2 (\sigma 2s)^2 (\sigma^* 2s)^2 (\sigma 2p_z)^2 (\pi 2p_x)^2$
$(\pi 2p_y)^2 (\pi^* 2p_x)^2 (\pi^* 2p_y)^2$

$$\therefore \text{B.O.} = \frac{10-8}{2} = 1$$

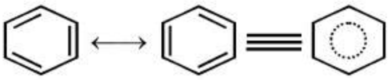
$\therefore$ N_2 has the highest bond order = 3.

196. (c) $\text{B.O.} = \frac{1}{2}[N_b - N_a] = 0$; cannot exist

197. (d) In this configuration, there are four completely filled bonding molecular orbitals and one completely filled antibonding molecular orbital. So that $N_b = 8$ and $N_a = 2$.

$$\therefore \text{Bond order} = \frac{1}{2}(N_b - N_a) = \frac{1}{2}(8-2) = 3.$$

198. (c) Benzene has the following resonance structures–



Hence, its bond order is

$$\frac{\text{no of possible resonating structures}}{2} = 1.5.$$

199. (a) Molecular orbital electronic configuration of these species are :

$$O_2^-(17e^-) = \sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \sigma 2p_z^2,$$
$$\pi 2p_x^2 = \pi 2p_y^2, \pi^* 2p_x^2 = \pi 2^* p_y^1$$

$$O_2(16e^-) = \sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \sigma 2p_z^2,$$
$$\pi 2p_x^2 = \pi 2p_y^2, \pi^* 2p_x^1 = \pi^* 2p_y^1$$

$$O_2^{2-}(18e^-) = \sigma 1s^2, \sigma^* 1s^2, \sigma 2s^2, \sigma^* 2s^2, \sigma 2p_z^2,$$
$$\pi 2p_x^2 = \pi 2p_y^2, \pi^* 2p_x^2 = \pi^* 2p_y^2$$

Hence number of antibonding electrons are 7, 6 and 8 respectively.

200. (d) $\sigma_b^2 \sigma^{*2}_a \sigma_b^2 \sigma_a^{*2} (\pi_b^2 = \pi_b^2) \sigma_b^1 (N_2^+ = 13 \text{ electrons})$

it contains one unpaired electron hence paramagnetic.

201. (N) None of the given option is correct.

The molecular orbital configuration of the given molecules is

$H_2 = \sigma 1s^2$ (no electron anti-bonding)

$Li_2 = \sigma 1s^2 \sigma^* 1s^2 \sigma 2s^2$(two anti-bonding electrons)

$B_2 = \sigma 1s^2 \sigma^* 1s^2 \sigma 2s^2 \sigma^* 2s^2 \left\{\pi 2p_y^1 = \pi 2p_z^1\right\}$

(4 anti-bonding electrons)

Though the bond order of all the species are same (B.O = 1) but stability is different. This is due to difference in the presence of no. of anti-bonding electron.

Higher the no. of anti-bonding electron lower is the stability hence the correct order is $H_2 > Li_2 > B_2$

202. (a) Molecular orbital configuration of

$$N_2^{2-} = \sigma 1s^2 \sigma^* 1s^2 \sigma 2s^2 \sigma^* 2s^2 - \begin{cases} \pi 2p_x^2 \\ \pi 2p_y^2 \end{cases} \sigma 2p_z^2 \begin{cases} \pi^* 2p_x^1 \\ \pi^* 2p_y^1 \end{cases}$$

$$\text{Bond order} = \frac{10-6}{2} = 2$$

$$N_2^- = \sigma 1s^2 \sigma^* 1s^2 \sigma 2s^2 \sigma^* 2s^2 \begin{cases} \pi 2p_x^2 \\ \pi 2p_y^2 \end{cases} \sigma 2p_z^2 \begin{cases} \pi^* 2p_x^1 \\ \pi^* 2p_y^0 \end{cases}$$

$$\text{Bond order} = \frac{10-5}{2} = 2.5$$

$$N_2 = \sigma 1s^2 \sigma^* 1s^2 \sigma 2s^2 \sigma^* 2s^2 \begin{cases} \pi 2p_x^2 \\ \pi 2p_y^2 \end{cases}, \sigma 2p_z^2$$

$$\text{Bond order} = \frac{10-4}{2} = 3$$

$\therefore$ The correct order is $= N_2^{2-} < N_2^- < N_2$

203. (a) Hydrogen bonding is not possible in HI due to low electronegativity of iodine. So, hydrogen bonding would not affect boiling point of HI.

204. (d) HF form linear polymeric structure due to hydrogen bonding.

205. (c) B, C and D form intermolecular hydrogen bonding while A form intramolecular hydrogen bonding due to proximity of oxygen and hydrogen.